

INSTRUCTION IN NATURE OF SCIENCE AND INQUIRY WITH  
UNDERREPRESENTED STUDENTS: BEING EXPLICIT ABOUT SCIENCE

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# INSTRUCTION IN NATURE OF SCIENCE AND INQUIRY WITH UNDERREPRESENTED STUDENTS: BEING EXPLICIT ABOUT SCIENCE

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This dissertation presents analyses of an instructional approach combining inquiry-based science teaching with instructionally congruent practice and explicit instruction in nature of science (NOS) through the context of the Fossil Finders curriculum unit in an urban fifth grade classroom serving underrepresented and English language learning (ELL) students. I draw on sociocultural theories of learning and identity to consider how this instructional approach may engage students in science learning and facilitate negotiation of understandings about science.

A key argument posed is that instructional approaches that engage students in the activities of science, through authentic investigation, provide opportunities for students to participate in the activities of science and interact with the scientific community of practice. Further, I argue that integrating instructionally congruent practice and explicit instruction in NOS with inquiry-based instruction increases the accessibility of science by taking cultural and linguistic differences of both students and science into account. The added component of explicit instruction in NOS as a multicultural approach differentiates this research from other studies focused on science instruction for underrepresented students.

Primary data sources include (a) video and fieldnotes of 13 instruction days in the classroom, (b) interviews with five focus students and their parents, (c) content-

matter pre-post assessments, inclusive of questions focused on views about NOS, and (d) student work samples. Together, these data illustrate how the teacher implemented the combined instructional approach, and how the students responded to this form of instruction. I illustrate how a framework combining these three approaches is implemented by a teacher with limited background in science, thereby exposing the potential for this instructional approach to be replicated. Results indicate student content-matter learning and how students' views about science are reshaped from mainstream cultural views about science to more informed understandings through participating in the data collection phases of scientific research in the context of their classroom. These findings are compelling given the growing number of students from backgrounds that have been historically underrepresented in the sciences in schools and the need to provide these students with culturally relevant instructional approaches.

## **BIOGRAPHICAL SKETCH**

My journey related to asking questions about inquiry and science education for underrepresented students began with informal teaching experiences at the Exploratorium Museum of Science, Art, and Human Perception. It was there that I wondered how English language learning (ELL) students would interact with and learn from English language descriptions of exhibits. This experience was followed by formal science teaching experiences at George Washington High School in San Francisco. While working with students from diverse cultural and linguistic backgrounds, I began to question *why* there were underrepresented students in the sciences in the first place. I began to wonder whether traditional science instruction was engaging these students in learning and whether differences across academic, scientific, everyday uses of language formed barriers to the science learning. Using my background with inquiry and academic preparation for working with ELL students, I compiled a field project merging inquiry-based instructional approaches in science with language learning strategies to complete a master's degree at the University of San Francisco in 2005. However, my questions about the accessibility of science for students from diverse backgrounds remained unanswered. Further studies at the Department of Education at Cornell University opened avenues to pursue these questions. The work presented in this dissertation considers both the theoretical challenges to science learning brought about by science instruction and practical approaches for teachers to apply. The completion of this dissertation work also draws to a close a full circle of studies at Cornell, where I completed my undergraduate work in the field of Natural Resources in 2000. These undergraduate learning experiences later informed my classroom environmental science teaching experiences.

To my former students, who inspired me to pursue this research:  
May your journeys across different cultural ways of knowing be filled with learning.

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## **LIST OF ABBREVIATIONS**

CoP- Community of Practice

ELL- English language learner/s

ELP- English language proficiency

FF- Fossil Finders

IC- Instructional Congruency

NAS- National Academy of Sciences

NOS- Nature of Science

NRC- National Research Council

NSES- National Science Education Standards

## CHAPTER 1

### INTRODUCTION

Linguistically and culturally diverse English-language learning (ELL), Latino, Native American, black, and other non-mainstream student groups remain underrepresented in high school science classrooms, science-related majors in universities, and science-related careers (Lee & Luykx, 2006). Efforts to close this gap in achievement and raise science aptitude on a national scale have mainly focused on increasing accountability and evaluation measures. This has resulted in greater focus on test preparation in urban schools, which serve many of the students that are underrepresented in the sciences, rather than reconsidering how science is taught (Settlage & Meadows, 2001). Test-oriented preparation does not reflect the practice of actual scientific work; instead, it reduces science learning to the rote memorization of scientific facts (Brown, Collins, & Duguid, 1989). Further, traditional instructional approaches provide instruction in science content that is devoid of the context of scientific activities and ways of knowing. Thus, traditional and test-based instruction may serve to reinforce the gap in achievement. While reasons attributing to the underrepresented nature of certain population groups in the sciences are many and complex, the underlying causes for differential achievement in science have not been addressed and responded to (Fine, Jaffe-Walter, Pedraza, Futch, & Stoudt, 2007). Without directing greater attention to how science is taught in schools and how it may align with students' diverse racial, cultural, and linguistic backgrounds and understandings, certain student groups will likely remain underrepresented in the future.

Science education reforms that emphasize engaging students in actively *doing* science rather than passively *learning about* it (National Research Council [NRC],

1996) as an alternative to traditional instruction, provide promise for involving diverse student groups in science learning. An inquiry-based science classroom would ensure that the learner: engages in scientifically oriented questions, gives priority to evidence in responding to questions, formulates explanations from evidence, connects explanations to scientific knowledge, and communicates and justifies findings (NRC, 2000, p. 29). This approach requires shifting instructional practices from teacher-directed to student-centered approaches, thereby having teachers share scientific authority in the classroom (Crawford, 2000). An instructional approach embracing inquiry would also model the authentic work of scientists in their communities of practice (CoP)(Wenger, 1999). Roth and Calabrese Barton (2004) describe how students marginalized in science classrooms by traditional schooling approaches can demonstrate active and engaged learning through collaborative inquiry related to authentic research investigations.

Studies focused on inquiry-based instruction in classrooms serving linguistically and culturally diverse student groups at the elementary (Lee, Buxton, Lewis, & LeRoy, 2006; Rosebery, Warren, & Conant, 1992) and middle school levels (Amaral, Garrison, & Klentschy, 2002) have also demonstrated positive effects on students' academic achievement, language learning, and appropriation of scientific discourse. A recent pilot study on the nature of instruction in a classroom using inquiry with Latino middle-school student groups in New York City provided some evidence for effectiveness of using inquiry as an instructional method to engage students in science learning (Meyer & Crawford, 2008). Nonetheless, involving underrepresented students in inquiry-based instruction may not be enough to facilitate developing deeper understandings about science. Research focused on science instruction with underrepresented student groups point to cultural differences continuing to challenge these students in science learning, despite innovative

instructional approaches through inquiry. Lee (2002) argues that ELL students from underrepresented backgrounds are supported in making personal connections to science learning when science instruction is culturally congruent, meaning “teachers integrate academic disciplines with students’ linguistic and cultural experiences to promote academic achievement” (p. 66). Instructional approaches combining inquiry with culturally relevant teaching, through instructional congruency (IC) may bolster inquiry-based instruction for these student groups. Features of IC include the use of everyday language in the classroom, linguistic scaffolding to enhance science learning, the inclusion of diverse cultural experiences and materials, and the sharing of scientific authority as a part of science instruction.

Multicultural education theorists direct attention beyond differences in language and instructional approaches to how cultural differences in worldviews may contribute to challenges in science learning. Worldviews are constituted by the epistemological framings of understandings. Differences in student worldviews and the epistemological framing of science as taught in schools may not be possible to mediate in the context of traditional school-based science instruction (Cobern, 1993). Recognizing the cultural differences between student understandings and school-based science, Aikenhead (1996) claims “science educators, Western and non-Western, need to recognize the inherent border crossings between students’ life-world subcultures and the subculture of science” (p.2). Aikenhead further calls for the “need to develop curriculum and instruction with these border crossings explicitly in mind, before the science curriculum can be accessible to most students.”

Other multicultural education theorists uphold the need for explicitness in instruction to increase the accessibility of science content-matter for students (Banks, 1996; Erickson, 1997; Ladson-Billings, 1995). This is because the subculture of school may differ from students’ home cultures. These cultural differences may be



particularly exacerbated in science instruction, where not only the subculture of school may differ from students' home cultures, but science may constitute another subculture. Making science explicit through instruction is thus particularly relevant for students whose worldviews and subcultures differ from the cultural values of school-based science. Science education researchers' advocacy for explicit instruction in nature of science (NOS) (Lederman, 1992, 2004; Schwartz, Lederman & Crawford, 2004) aligns with multicultural education theorists' call for explicitness in instruction as a means of bridging cultural differences.

Explicit instruction in NOS would include demystifying science and framing science content matter within its epistemological framework. For example, instruction in NOS would reframe science as a social process of knowledge production rather than simply factual information. Explicit instruction in NOS accompanying authentic learning experiences may be particularly significant for underrepresented student groups. Bolstering science teaching with explicit instruction in NOS may support students in better framing their understandings of science and negotiating cultural border crossings. A combined instructional approach between inquiry, IC, and explicit instruction in NOS may thus facilitate science learning for underrepresented student groups.

Inquiry and IC, and inquiry and explicit instruction in NOS, have been grouped together as instructional approaches previously; however, all three have not yet been merged in theory or practice. More research is needed to understand how an instructional approach combining inquiry, IC, and explicit instruction in NOS may engage underrepresented and ELL students in science learning and foster better understandings of science. The Fossil Finders investigation presented an opportunity to investigate an instructional approach that combined the three in an urban classroom serving underrepresented students. Using a case study design, this study explored the

nature of instruction in this classroom, and how the use of inquiry combined with IC and explicit instruction in NOS fostered culturally congruent science learning experiences for underrepresented and ELL students.

***Relevant terms for this study include the following:***

*Authentic* - the “ordinary practices of [a] culture” as bounded by context (Brown, Collins & Duguid, 1989, p. 34)

*Borders* – Sociocultural differences that are difficult to traverse (i.e. due to epistemic differences, power relations)

*Boundaries* – Traversable sociocultural differences (i.e. linguistic)

*Constructivism* - theory about how individuals learn, where people construct their own meanings and knowledge through experience and reflection.

*Cultural Congruency* - where instructional methods are aligned with students’ cultural understandings and uses of language.

*English language learning (ELL)* - term to designate students below a certain level of English language proficiency; oftentimes recent immigrants.

*Explicit* - term used when discussing inquiry instruction and the nature of science.

Refers to educators approaching instruction in the nature of science as content-matter learning and making connections to scientific practice.

*Funds of Knowledge*- cultural resources “generated through the social and labor history of families and communicated to others through the activities that constitute household life, including through the formation of social networks that are central to any household’s functioning within its particular environments” (Gonzalez, Moll, & Amanti, 2005, p. 18)

*Implicit* - term used to describe nature of science learning as an embedded part of

inquiry-based instruction and the ability of students to understand science as a result of inquiry activities.

*Inquiry* - refers to “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (NRC, 1996, p.23).

*Instructional Congruency (IC)*- an application of cultural congruency, where instructional methods are aligned with students’ cultural understandings and uses of language, to a particular subject-matter, such as science.

*Limited English Proficiency (LEP)*- English language learning students testing below a certain level of academic language proficiency. In this study, these students were receiving additional language learning support.

*Nature of Science (NOS)* - refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent in the development of scientific knowledge (Lederman, 1992).

*Traditional* – referring to didactic, teacher-centered instructional style.

*Underrepresented student groups* - students proportionally underrepresented in the sciences in relation to their white and Asian counterparts.

*Non-mainstream* – a term use to describe Latino and black students in urban schools to acknowledge that they are not minorities in these educational settings (Lee & Luykx, 2006).

### ***Research questions***

This study considers how a classroom environment involving inquiry, instructional congruency, and explicit instruction in NOS may engage underrepresented and ELL students in science learning and foster better understandings of science. The implementation of the Fossil Finders (FF) investigation in a classroom serving underrepresented students provided a context in which to consider how an instructional approach combining inquiry, IC, and NOS, was implemented and how students responded. The two research questions driving this investigation are:

- 1) How did the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach?
- 2) How did underrepresented students experience and respond to an instructional approach combining inquiry, instructional congruency and explicit instruction in NOS?

The purpose of focusing on the teacher was to gain a better understanding of how she implemented the Fossil Finders instructional unit using the combined instructional approach. The curriculum used in this investigation was in its pilot phases and was enacted by a teacher relatively new to the use of inquiry in science instruction. An understanding of how this teacher was able to implement this instructional approach would inform the potential for it to be used by teachers with similar background preparation in urban school settings. The purpose of focusing on students was to learn how they responded to the instructional approach used in the classroom. An understanding of how students responded to this form of instruction would determine whether there may be gains through the use of this instructional approach.

Both of the driving research questions were broken down into parallel sub-questions (a, b, and c), which aligned with inquiry, instructional congruency, and explicit instruction in NOS as separate constructs (Table 1). The purpose of subdividing each research question into constructs was to direct greater attention to each of these elements of instruction. Two additional research sub-questions (d) were added to evaluate how the teacher brought the three focus constructs together in her classroom and how student science learning was supported through this instructional approach.

**Table 1. Research Sub-questions**

<b>Sub-question</b>	<b>Constructs/Topic</b>	<b>Teacher (<i>Research Question 1</i>)</b>	<b>Students (<i>Research Question 2</i>)</b>
<b>A</b>	Inquiry	In what ways does the teacher engage students in inquiry?	In what ways do students engage in scientific inquiry?
<b>B</b>	Instructional Congruency (IC)	To what extent does the teacher use IC strategies for teaching science?	How do students bridge everyday understandings and science?
<b>C</b>	Nature of Science (NOS)	In what ways does the teacher make NOS explicit to students during instruction?	What are students' views of NOS and how do these change during the investigation?
<b>D</b>	Evaluation	How are inquiry, IC, and explicit instruction in NOS brought together in this teacher's classroom?	How are students supported in content-area learning?

The literature review in the next section provides background rationale related to the focus on culturally congruent inquiry-based instruction combined with explicit instruction in NOS as a combined instructional approach.

## **CHAPTER 2**

### **LITERATURE REVIEW**

This research study considers how an innovative instructional approach to science instruction, which utilizes inquiry, IC, and explicit instruction in NOS is enacted in a classroom setting, and how it may engage underrepresented students in science learning and foster better understandings of science. The theoretical underpinnings of this research consist of combining three instructional approaches--that of inquiry, IC, and explicit instruction in NOS. The notion that inquiry-based science approaches may engage students in the activities, culture, and context of school science (NRC, 1996, 2000) is fundamental to this combined approach. The literature reviewed below thus describes theoretical bodies of work and research related to the use of inquiry-based instructional approaches in classrooms serving underrepresented students. These studies for the most part demonstrate positive results.

From a standpoint that recognizes science as a cultural way of knowing however, sociocultural literature reviewed below problematizes the use of inquiry and considers the challenges that inquiry-based instruction may pose to diverse student groups. This entails a perspective that science learning may require the negotiation of prior-held every-day and cultural understandings with scientific culture. These understandings include language and culture, both of which play an integral part in shaping student worldviews and identity, and may or may not align with the culture of science. While inquiry-based instruction assumes a constructivist approach, building upon students' prior understandings, a socio-constructivist approach would consider

the role diverse cultural understandings may hold in science learning. The field of multicultural education offers recommendations for creating learning environments with socio-culturally relevant instruction. This literature review draws on tenets from the field of multicultural education to propose a practical approach to science instruction through a theoretical model combining inquiry with culturally relevant instructional approaches.

The first part of this literature review will define inquiry-based instruction and discuss research focused on using inquiry with underrepresented students. The following section presents research that establishes an understanding of science as a culture and discusses sociolinguistic and socio-cultural challenges in science learning and the roles that language, culture, worldviews, and identity may assume. The subsequent section will draw from the field of multicultural education to suggest how opportunities for negotiating cultural challenges into science may be afforded through the context of engaging in scientific activity. This includes adopting culturally congruent instructional strategies as well using explicit instruction in NOS to demystify science. These instructional approaches are brought together into a theoretical model guiding this research. Thus, this literature review will be divided into the following five sections: (a) Inquiry-based instruction in science; (b) science as a cultural community; (c) increasing the accessibility of science through multicultural instruction; (d) instruction toward mediating between scientific and other cultural understandings; and (e) an instructional approach combining inquiry, IC, and NOS.

### ***Inquiry-based instruction in science***

Science education reforms that emphasize engaging students in actively *doing* science rather than passively *learning about* it (NRC, 1996) provide promise for involving underrepresented, as well as mainstream, student groups in science learning.

Alternative approaches to science instruction, such as inquiry, focus on science teaching and learning to include the knowing, doing, and talking processes of science (Rutherford & Alghren, 1990). Inquiry embodies an instructional approach based on constructivist learning theory, where students use existing understandings as a foundation for expanding their knowledge about science. From this theoretical stance, scientific knowledge is co-constructed through participation in scientific activities (Driver, Asoko, Leach, Mortimer & Scott, 1994).

The NRC describes inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work” (1996, p. 23). Inquiry is also described as the “activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world” (NRC, 1996, p. 23). These two definitions contain both the context of authentic scientific activity for scientists and the processes of science learning for students. Inquiry-based science instruction also models the activities of scientists by requiring that a learner: (a) engages in scientifically oriented questions; (b) gives priority to evidence in responding to questions; (c) formulates explanations from evidence; (d) connects explanations to scientific knowledge; and (e) communicates and justifies findings (NRC, 2000, p. 29). Similarly to what scientists do, inquiry involves students in *thinking* about scientific questions, making sense of data, and connecting their own explanations to scientific ideas. In doing science, students are actively engaged in doing the *thinking and learning* related to scientific work. An inquiry-based instructional approach thus provides a means for students to engage in scientific activities and culture in the classroom (Schwartz, et al., 2004).

This instructional approach forms a signification point of departure from traditional science teaching and learning in classrooms. Traditional textbook-based instruction makes use of the scientific method to introduce scientific processes.



Inquiry, however, differs from traditional instruction in that its features are recursive rather than a linear set of steps. For example, a scientifically oriented question may be modified upon data collection and again based on findings through inquiry. Further, inquiry differs from “cookbook” labs in which answers and methods are pre-determined. In contrast with tightly structured “cookbook” labs, guided inquiry allows the student to figure out the solutions for herself, and open inquiry allows students to pursue ill-structured problems, where there is no set result and in which evidence is used to construct explanations. Inquiry also differs from “hand-on” approaches to science instruction, where students interact with physical objects and implement science-related tasks without developing understanding of the nature of scientific research (Huber, R. & Moore, C., 2001).

The implementation of inquiry-based instruction also differs from that of traditional instructional approaches. In a traditional science classroom, teachers may use a didactic approach to teach about science. This textbook style of instruction does not model the activities of scientists, who engage and grapple with research questions. Inquiry further requires shifting from teacher-directed to student-centered approaches (Crawford, 2000). Within this approach, teachers become learning facilitators and share scientific authority with their students.

Moving beyond traditional science instruction to increased attention on the processes of science and scientific discourse may provide greater opportunities for better connecting underrepresented students to science. Rather than simplifying science learning to content-matter acquisition, engaging students in inquiry-based learning provides a context for authentic experiences. This in turn may create possibilities for greater relevancy to students and provides students with increased opportunities for negotiating between scientific and cultural understandings. Moreover, involvement in authentic scientific activity may provide opportunities for

mediation between the separate worlds of science, school, and students. Not only would the context of investigation create opportunities for students to participate in scientific processes, but it would also embed science learning within the activities of scientific culture. A number of studies have focused on the use of inquiry-based instructional strategies with underrepresented and ELL students. The next section of this literature review focuses on this research.

### *Research on inquiry with diverse students*

Reform initiatives aimed at providing educators with professional development to encourage the use of inquiry-based instruction in classrooms have demonstrated positive effects on the academic achievement of linguistically and culturally diverse urban student groups at the elementary and middle school levels. These studies focus on differing aspects of learning and add to a growing body of literature of instructional approaches that may serve to benefit underrepresented students in science.

Warren et al. (2001) developed two case studies on the different ways students from low-income, linguistic, racial, and ethnic minority communities' approach sense-making in science through the Chèche Konnen Project. Researchers found that in using everyday ways of knowing in school science instruction, students were capable of using their own language skills to conduct intellectually rigorous work that is connected to scientific knowing and practice. Thus, they argue that it is important to consider the "ways of talking and knowing that children from diverse communities bring to science," (p. 546) rather than to view them as being disconnected from the "complexity, generativity, or precision" of learning science (p. 548).

In a study by Amaral, Garrison, & Klentschy (2002), the effects of a district-wide adoption of inquiry-based science curriculum through "kit-based science" on ELL students were measured. Kit-based science involves a move away from

traditional text-book based instruction and entails a hands-on instructional approach. The structural changes adopted by the district to support student learning included teacher professional development, inter-disciplinary curricular coordination within school sites, and an increase in materials made readily available to instructors for science exploration. Researchers conducted a four-year longitudinal study and tracked the progress of 615 fourth grade students and 635 sixth grade students involved in the initiative. Students were grouped by English language proficiency and number of years in the program (0-4). Student learning was evaluated through formative assessments in the form of student notebooks and summative assessments in the form of standardized examinations. As students progressed through grade-levels, they were evaluated using state wide standardized examinations in science, reading, writing, and mathematics (SAT-9, Form T, Intermediate 1 for Grade 4; SAT-9, Form T, Intermediate 3 for Grade 6). Data were processed through correlation and linear regression tests. Findings demonstrated an increase in the academic achievement of ELL students in all domains of testing related to an increase in time exposed to the program.

However, the study did not carefully define its use of inquiry in kit-based science. Thus, it is unclear whether the district in this study implemented inquiry aligned with NRC definitions (NRC, 2000). Because there is a possibility that kit-based science could entail cookbook labs, it does not necessarily connote student-centered inquiry. Consequently, the extent to which students participated in authentic inquiry through this program remains uncertain. Moreover, while the researchers provided substantial data on the ethnic, cultural, and socioeconomic backgrounds the surrounding community and students, little information was given on the context of the classroom. While research findings demonstrated growth in student achievement, the study did not account for the effects of student maturation or a comparison of

results with a control group. Thus, further research is needed to determine the effects of this instructional approach.

In a more recent study, Lee, Deaktor, Hart, Cuevas, & Enders (2005) researched the effects of a year-long curriculum intervention on the science and literacy achievement of culturally diverse students in a large urban school district. The researchers implemented a multipart intervention that included curriculum development, teacher professional development, and classroom instruction in their study. The curriculum was designed to employ inquiry-based methods of instruction with greater IC to the cultural backgrounds of these students. IC is described above as a method of instruction that is culturally congruent to the communication and interaction patterns that are familiar to students.

In the Lee et al. (2005) study, data collection and analysis involved 53 third and fourth grade classrooms with 1,523 participating students from mixed ethnic, linguistic, and socioeconomic backgrounds was broken down by ethnicity, English language proficiency, and socioeconomic status (SES). Furthermore, teachers involved in the study were described according to ethnicity and the student populations which they served. Researchers used pre-and post-tests to measure and compare student learning in science and literacy to each other and to rankings in the National Assessment of Educational Progress and to the Third International Mathematics and Science Study. Findings demonstrated significant growth in science and literacy at both grade levels. However, researchers noted that achievement gaps widened between demographic subgroups at the end of the school year for third graders and narrowed for fourth graders. Thus, the researchers concluded that there may be a delayed impact in this form of instruction.

Another study analyzing students' abilities to use inquiry was based on the same intervention (Cuevas, Lee, Hart, & Deaktor, 2005). Researchers posed questions

to 25 third and fourth grade students prior to and after the instructional intervention. The researchers based their questioning on an elicitation protocol related to methods of inquiry about conducting a science experiment and recorded students' verbal responses. Students involved in the elicitations represented the overall student group demographics. The elicitation responses were scored according to a rubric and quantitatively analyzed. Results showed that the intervention had a positive effect regardless of the grade, achievement, gender, ethnicity, SES, home language, or English proficiency of students. Furthermore, results indicated that low achievers and students with low-SES made greater gains than higher achievers and students with higher SES. Researchers claim that "the results of this study indicate that inquiry-based instruction effectively promoted these increases" (p. 351). The interview questions developed for this study align with research-based recommendations for measuring students' understandings of inquiry (Chinn & Malhotra, 2002). They also provide a useful tool for evaluating understandings of science for students with differing levels of English language proficiency (ELP).

Researchers also evaluated the effects of the same intervention (Lee et al., 2005) abilities to conduct inquiry in another study (Lee, Buxton, Lewis, & LeRoy, 2006). The study analyzed the qualitative data in the pre-elicitations and post-elicitations of students with respect to the instructional intervention to measure their growth. Results indicated that students demonstrated enhanced abilities in the use of empirical evidence to support their theories in science. In addition, results demonstrated that impact of the intervention was amplified in the case of marginalized students and students of lower SES backgrounds. There was no evidence of limited ELP levels interfering with students' abilities to express their ideas during pre-elicitations, whereas findings demonstrated that they had difficulties expressing their

learning in post-elicitations. Researchers did not attribute this to students' conceptual growth in science, but rather, their developing language abilities.

Together, this body of work serves to support the continued use of inquiry-based approaches in classrooms serving underrepresented and ELL students. These studies demonstrate moderate student gains in science and other areas resulting from a shift toward inquiry-based instruction in schools. Despite the positive indications for engaging students in active science learning, actually bringing inquiry-based science instruction into schools has been met with numerous challenges. Not only does the implementation of inquiry-based instruction require robust teacher preparation and a supportive school environment (Crawford, 2007), additional obstacles include the movement toward greater standardized testing. Efforts to increase standardized test-scores are often met with an increased emphasis on teacher-directed instructional approaches. This is especially evident in urban schools that serve underrepresented students (Settlage & Meadows, 2001). The challenges of bringing innovative instructional approaches to the students that may need them most are confounded by the lack of teachers with appropriate preparation. Studies demonstrate that urban school settings, which serve many students from underrepresented backgrounds, are challenged with high teacher turn-over and underprepared teachers (Lankford, Loeb & Wyckoff, 2002). Because inquiry-based instruction is especially difficult for teachers to implement without adequate experience and preparation (Crawford, 1999), this is especially problematic. These challenges to the implementation of inquiry with underrepresented students present the need to justify the use of inquiry with these student populations and for greater teacher professional development.

Nonetheless, inquiry presents a promising point of departure from traditional classroom instructional approaches, which have not successfully reached all students. Given disparity in student achievement in science, and ultimately the underrepresented

nature of certain groups in the field of science, it is important to both further consider the potential benefits of inquiry and critically examine it as an instructional approach. The research reviewed above focuses on scientific content and language learning opportunities presented to underrepresented students through inquiry. However, it does not consider the role of inquiry in transmitting an understanding of science as situated within the activities of scientific culture. Further research is necessary to learn more about the cultural experiences of students involved in inquiry and to determine how students make sense of science by participating inquiry.

### ***Science as a Cultural Community***

Through inquiry-based instruction, students have greater opportunities to engage in science learning by participating in scientific activities. In this sense, science learning becomes an appropriation of scientific knowledge and culture through active engagement in the practices of science.

An anthropological lens cast on science would frame it as a socially constructed “figured world” with its own corresponding cultural meanings, codes, and language. Holland, Lachicotte, Skinner, & Cain (1998) elaborate on the ramifications of socially constructed worlds:

Culturally figured worlds or figured worlds...include all those cultural realms peopled by characters from collective imaginings: academia, the factory, crime... these are worlds made up...“webs of meaning.” Figured worlds take shape within and grant shape to the coproduction of activities, discourses, performances and artifacts. A figured world is peopled by the figures, characters, and types who carry out its tasks and who also have styles of interacting within, distinguishable perspectives on, and orientations toward it (p. 31).

These guidelines also frame science as a figured world, which as a field entails its own language, activities, varying degrees of members, and rules for membership. To name a few, these may include the experiment, methods of investigation, guidelines for

publications, and the scientist and peer-review process when it comes to science. Science, as a cultural figured world, both includes and excludes individuals from participation based on their identities in relation to it. Given accessibility, it also shapes and is shaped by the identities of its members. These aspects of figured worlds begin to converge with the notions of culture<sup>1</sup>, or the dynamic characteristics of a group of individuals, with the community itself. A discussion of science as culture must therefore include a discussion of the overlapping school, science, and student communities when it comes to school science.

Considerations of science as culture therefore have important implications for science education. First, they force us to reconsider science education in schools. Are we preparing students to understand science through traditional science instruction? Next, they raise concerns related to the accessibility of science based on students' cultural backgrounds. Is science accessible for all students? And, what does membership in science entail? Further, they question what the learning experiences of students may be in settings that merge school with authentic science.

Viewing science as culture enables us to view the extant gap between science and school science instruction (Brown et al., 1989; Chinn & Malhotra, 2002). Science, as a socially constructed way of knowing that is implicated within its own framework and activities, is very different than science, the a body of knowledge which is traditionally taught in schools. Educational researchers seeking to promote deeper understanding of science in schools and boost student achievement in science have attempted to bridge science content area learning with the activities, culture and context of science. These efforts align with Brown et al.'s (1989) notion of situated

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<sup>1</sup> Culture is seen as the dynamic and shifting characteristics of a community.



cognition, a view of knowledge as inseparable from the activity, context, and culture from which it arises.<sup>2</sup>

Lave and Wenger (1991) consider the situated knowledge of a community of practice (CoP) and learning that occurs as part of social interaction within that group. A CoP is a group of individuals with shared interests and activities. A learner's participation in a CoP becomes a way of "both absorbing and being absorbed in- the 'culture of practice'" (p. 95). Thus, by virtue of participating in the activities of a CoP, an individual engages in learning and in the process, becoming a part of that CoP.

These conceptions about CoPs are particularly relevant to considering the cultural learning experiences of students in schools through traditional instruction in science. Lave and Wenger offer traditional science education in schools as an example, to point out that, in schools, students are not introduced to scientific communities, but rather, to a community of schooled adults. They further suggest that "the reproduction cycles of the [scientific] community start much later, possibly only in graduate school (Traweek, 1988)" (p. 100). Educational reforms seek to bridge the gap between school science and the scientific CoP by introducing students to the activities of science. These reforms use inquiry as a vehicle and align with recognizing scientific knowledge as situated within its culture and practices.

Restructuring school science instruction by introducing inquiry into the classroom situates science learning within a scientific context. Thus, there is theoretical justification for the use of inquiry in classrooms. The premises of engaging

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<sup>2</sup> The use of the term *context* can become confounded between the schema of an activity and physical setting in which an activity occurs. Using Rogoff's (1995) example of Girl Scout cookie sales exemplifies the context of activity whereas a focus on the location of this activity, such as a community center, would describe the physical location. In this paper, the use of the word context refers to the schema of scientific inquiry rather than the context of school, as this use of the term more closely aligns with the nested meaning of context in situated cognition.

students in the context of investigation are consistent with not only viewing scientific knowledge as situated, but also initiating students into a scientific CoP. Lave and Wenger thus offer a viable construct for considering the intersection of school and science communities through an overlap of activity: authentic investigation. By engaging in inquiry through the context of an investigation, students participate in the activities of science and become familiarized with scientific practices. In this way, the CoP perspective suggests mechanisms through which the learner gradually becomes a part of a community and offers insight on the dynamic processes of science learning.

Although participation in activities of a CoP may result in learning, it is important to consider the skepticism related to science learning through participation in the school science activities. Science education researchers (Chinn & Malhotra, 2002) problematize the ability of schools to authentically implement scientific investigations given structural constraints. Researchers further point out how classroom instruction may serve to misrepresent certain scientific practices (Driver et al., 1994). For example, “scientists build on each other’s work in a way that is absent in simple school science” (Chinn & Malhotra, 2002, p. 190). Further, the argument that school science education differs from participating in a community of scientists finds support among science education researchers; however, even an attempt to implement inquiry in schools already makes a significant point of departure from traditional instruction. Research suggests that actively learning science, rather than passively learning *about* science, can occur provided guidance, authentic activities, and contextualized investigation (Driver et al., 1994; Chinn & Malhotra, 2002; Schwartz et al., 2004). In this way, bringing inquiry into the space of schools may nonetheless create opportunities to engage underrepresented students in the culture of science within schools.

Most critiques about inquiry focus on the convergence between classrooms and scientific culture and the ability of classrooms to adopt and adapt to scientific cultural practices. However, the experience and milieu, or life-world, of students is often overlooked in the process. For example, while students' participation in inquiry would assist them in acquiring scientific knowledge, skills, and understanding as they engage with the scientific community, this relationship is unidirectional. In this case, the learner is brought into a particular community, rather than given the opportunity to establish a reciprocal relationship of shared understanding. Moreover, little is known about the potential cultural challenges learners may face through participating in inquiry. Drawing from sociocultural learning perspectives may facilitate greater understanding of how learners and their cultural and community-based understandings are implicated in science learning. These perspectives lead to the following question: what does it mean to engage underrepresented students in the culture of science? Viewing science as a cultural way of knowing thus offers another perspective for examining the challenges that underrepresented students face in science learning. In light of the potential benefits that inquiry-based methods of science instruction may bring to engaging students from underrepresented student groups in science, the following section of this literature review focuses on sociolinguistic and sociocultural considerations for curbing differential school achievement in science.

### ***Increasing the accessibility of science through multicultural instruction***

Greater attention directed to science learning as *enculturation* (Driver et al., 1994) creates the space for examining differential achievement in science and science learning as a borderland of cultural interaction. In this space, interrelated linguistic and cultural challenges to science learning may persist despite innovative instructional approaches that engage students in the activities of science. Some researchers point to

the home-based cultural tools and understandings of students, or *funds of knowledge*, which may differ from those of science (Gonzalez, Moll, & Amanti, 2005). Other researchers describe inconsistencies in cultural communicative patterns impeding the science learning of underrepresented and ELL students (Lee & Fradd, 1998; Rosebery, Warren & Conant, 1992). These challenges consist of appropriating and making use of school-based, scientific, and English languages. Further, researchers point to world-view and epistemological disconnects as obstacles to science learning (Cobern, 1993; Aikenhead, 1996; Jegede & Aikenhead, 1999; Snively & Corsiglia, 2001).

Drawing from literature in multicultural education, I consider both the challenges and practical approaches to support students in navigating cultural boundaries and borders to science learning despite and related to innovative approaches through inquiry. *Boundaries* to science learning may consist of challenges in the instructional accessibility of science, such as differences in language use and interactive patterns in the classroom, while *borders* are formed by deeper epistemic differences in ways of knowing. Though differences in language and culture may form boundaries and borders to science learning, educational researchers use a variety of theoretical approaches to offer instructional strategies for addressing them. Boundaries and instructional strategies toward navigating them will be discussed in the first section; borders and ways in which they can be negotiated through instruction will be discussed in the next section.

#### *Underrepresented students and boundaries to science*

The accessibility of science instruction may be bounded by the linguistic and cultural attributes of science and schooling. For example, students developing English language skills may not be able to decode classroom teaching. In other cases, science-specific discourse and the activities of science may render instruction

incomprehensible. Several bodies of work relate language and underrepresented and ELL students engaged in inquiry-based instructional settings. This research represents multiple perspectives on the relationality of students, their linguistic abilities, and science, in light of students' participation in scientific investigations. For example, research related to the Chèche Konnen project directs attention to science learning through the use of students' native and everyday languages (Rosebery et al., 1992; Warren et al., 2001). Other research directs attention to English language acquisition through participation in inquiry-based activities (Stoddart, Pinal, Latzke & Canaday, 2000). However, Okhee Lee's work additionally considers the linguistic and cultural support needed by students engaged in inquiry-based science.

Lee and Fradd (1998) contend that science learning is not accessible to non-mainstream students through inquiry without further instructional support.

"Traditionally, science has been taught with the expectation that students will understand and learn when teachers present the content in scientifically appropriate ways... little consideration [has been given] to students' literacy, language, and cultural understanding" (p. 12). Lee (2003) further argues that not only do students need linguistic scaffolding, but students' cultural norms must also be brought into inquiry-based instructional settings:

although scientific inquiry is a challenge for most students, it presents additional challenges for students from cultures that do not encourage them to engage in inquiry practices of asking questions, designing and implementing investigations, and finding answers on their own. Cultural norms may also prioritize respect for teachers and other adults as authoritative sources of knowledge, rather than the development of theories and arguments based on evidence and reasoning" (p. 466).

In this sense, inquiry-based instruction must be framed in an accessible way to non-mainstream students, and cannot alone be expected to assist students in science learning.

### *Instructional congruency as a pathway*

Lee and Fradd's (1998) seminal work in considering underrepresented students' interaction with language and the culture of science provides a framework for increasing the accessibility of science instruction. Rather than assuming students' appropriation of language and scientific understandings through participation in scientific activities, the researchers direct attention toward modifying instruction to fit students' existing tools for mediating learning. They build on the construct of *cultural congruency*, where instructional methods are aligned with students' cultural understandings and uses of language, to offer a framework for IC in science education. Lee (2004) explains that while cultural congruency entails "teachers integrat[ing] academic disciplines with students' linguistic and cultural experiences to promote academic achievement" (p. 66), IC applies the construct of cultural congruency to a specific area of instruction, such as science education. In Lee's words, "the instructional congruence framework maintains that effective subject area instruction should combine consideration of students' cultural and linguistic experiences with attention to the specific demands of academic disciplines" (2004, p. 67).

In a later work Luykx and Lee (2007) introduce a framework for evaluating IC. This framework serves as a useful tool for evaluating the cultural congruency of science instruction by seeking the inclusion of the following features in science instruction: (a) a sharing of scientific authority; (b) a diversity of cultural experiences and materials; (c) the use of students' home languages in classrooms; and (d) the use of linguistic scaffolding to enhance meaning. The researchers describe:

The instructional congruence framework holds that academic content, as well as the cognitive and discursive practices associated with particular academic disciplines, are made more accessible and meaningful for students when they are purposefully mediated by students' linguistic and cultural experiences. As a guiding principle for

pedagogical practice, instructional congruence aims to help students acquire scientific understandings, inquiry practices, and discourse by taking into account the relation of these three domains to students' home culture and language, and by devising instructional strategies that address both the discontinuities and the continuities between the two broader bodies of knowledge (i.e., school science and students' prior linguistic and cultural knowledge). (Luykx & Lee, 2007, p. 425)

In this way, the features of the IC framework combine the mediation of scientific and cultural understandings with students' use of home language to gain understanding.

Moreover, they entail a student-centered approach to instruction, where students share the process of engaging in constructing scientific explanations.

Together, the features of the IC framework complement science reform efforts towards inquiry-based instruction and align with the body of research in multicultural education. For example, encouraging the sharing of scientific authority entails a shift from traditional teacher-centered instruction to a student-centered approach (Crawford, 2000). In this shift, teachers become learning facilitators rather than the primary sources of knowledge. The sharing of scientific authority is also an integral part of inquiry-based instruction. In this way, the IC framework upholds the use of inquiry as an instructional approach. Further components of the framework align with research in multicultural education. For example, bringing diverse cultural experiences and materials into a classroom invites and validates students' cultural backgrounds. This aligns with funds of knowledge approach, as described above and in more detail below (Gonzalez et al., 2005). Moreover, encouraging the use of home languages in science classrooms reflects the research-based findings of the Chèche Konnen Project described above. In using home language during instruction, students are not detracted from content-matter instruction (Banks, 1996, Nieto, 2004).

Research on English language development supports using linguistic scaffolding to enhance meaning (Cummins, 2000). Moreover, linguistic scaffolding could include making language switching codes between science and everyday language explicit to

students. For example, teachers would ask students, “how would you say that in scientific terms?” With the aid of linguistic scaffolding, students would be supported in learning both science and language.

These instructional strategies do not assume a “learning styles” approach, where cultural differences tend to be reduced to a static prescription of various instructional approaches for particular cultural groups (Gutierrez & Rogoff, 2003). Rather, these instructionally congruency strategies make use of bridging between instruction and student experiences by bringing linguistic scaffolding, everyday language, and students’ everyday and cultural experiences into the classroom. Similarly to Lipka et al.’s (1998) work with Yup’ik students in Alaska, the instructional congruence approach enacts a “both/and” approach rather than an “either/or” approach. This entails a classroom approach that uses both everyday and scientific ways and knowing, rather than an approach that differentiates between the two.

Through cultural validation and with the addition of language-based support, science learning can be likened to negotiating a boundary. In this sense, IC strategies may assist underrepresented students gain understanding in science while maintaining their own cultural identities. Nonetheless, assisting students through boundary-crossings into science with linguistic and cultural scaffolds may not be enough to address the borders to learning that may be established by differences in worldviews. For example, though this instructional approach considers students’ cultural backgrounds and instructional scaffolding approaches toward their academic success, it nonetheless falls short of considering the culture of *science* within instruction and how it may contradict students’ cultural understandings. Assuming that students are involved in inquiry, the theoretical model proposed in this study seeks to acknowledge students’ cultural ways of knowing as part of the learning process while also



recognizing scientific culture as a construct to be made explicit. This aligns with Southerland's (2000) notion of recognizing science as a human enterprise as a part of multicultural instruction in science. The following section of this literature review considers how to support students in negotiating understandings about science across borders, or deeper-set spaces of cultural divide.

### ***Instruction toward mediating between scientific and other cultural understandings***

Sociocultural views of science education extend the notion of cultural congruency to include epistemic and worldview perspectives. Science instruction may become culturally *incongruent* for underrepresented students with epistemic differences and contradicting worldviews (Cobern, 1993; Aikenhead, 1996, 2001; Ogawa, 1995; Jegede & Aikenhead, 1999). These cultural differences potentially constitute borders, or challenges rooted in epistemic differences, to science education and are rooted in the lack of opportunities to negotiate understandings, power differentials, and identity. Students that experience challenges to their world-views, or everyday and culturally-based understandings of the world as a result of science instruction may respond with resistance to science learning. The following section of this literature review will further describe worldview and epistemic challenges to science learning as well supporting students in making border-crossings in science learning.

### ***Science learning as a challenge to students' everyday ways of knowing***

As Jegede and Aikenhead (1999) describe, "for a majority of students, science teaching is experienced as an attempt to assimilate them" (p. 48). For these students in particular, science learning does not entail cultural congruency in deeper sense where epistemic underpinnings and worldviews align. This is because "a cultural perspective recognizes conventional science teaching as *an attempt* at enculturation or

assimilation—cultural transmission that supports or replaces a person’s life-world subcultures respectively” (Aikenhead, 1996, p. 20).

Similarly to literature on cultural borders (Erickson, 1997), where power differentials are at play in a borderland interaction Aikenhead (1996) draws attention to cultural borderlands in science learning. However, Aikenhead does not draw the distinction between traversable boundaries and rigid borders in his work. Rather, Aikenhead frames the rigidity of the border in science education based on its relationality to the learner. For example, challenges to science learning relate to whether the cultural and everyday ways of knowing of students are compatible with scientific ways of knowing. Aikenhead explains:

If the subculture of science generally harmonizes with a student’s life-world culture, science instruction will tend to support the student’s view of the world (‘enculturation’). On the other hand, if the subculture of science is generally at odds with a student’s life-world culture, science instruction will tend to disrupt the student’s view of the world by trying to replace it or marginalize it (‘assimilation’). (1996, p. 5)

Aikenhead also acknowledges that science learning is more accessible to student groups whose cultural ways of knowing align with scientific culture. More specifically, science learning is implicated in Western ways of knowing, an already accepted cultural norm for many mainstream students. Along this line, science learning becomes an additional challenge to the cultural ways of knowing of many non-mainstream students (mostly from underrepresented backgrounds). Moreover, science education becomes a border when it becomes “subtractive,” or marginalizes the world-views of students in relation to Western modern science. This is especially evident in science instruction for indigenous groups (Cobern & Loving, 2000). Several researchers consider ways to ease these cultural border crossings for students in science education.

As described above, Aikenhead emphasizes the importance of teachers supporting students in border-crossings into science. This includes teachers' acknowledgement of the differences between science and the life-worlds of their students. Aikenhead suggests that educators consider developing instructional approaches that better connect students' everyday life-world subcultures and the subculture of science. To this end, he combines the work of several anthropological theorists to point to the role of educators as "tour-guides" into the world of science in relation to their students, who may have varying degrees of border-crossings. A teacher may act as a coaching apprentice, travel-agent culture broker, or tour-guide to a student who is experiencing border crossing experiences into science.

Phelan, Davidson and Cao (1991) created an anthropologically-based model to describe student transitioning between multiple worlds. Aikenhead (1996) makes use of this model to describe border crossings into science as smooth, managed, hazardous, or impossible. These types of border-crossings depend on students' prior understandings and how they relate to science, as described above. Accordingly, student cultural and identity play an integral role in science learning. Aikenhead (1996) also draws from Costa, who aligns these degrees of border crossings with students' degrees of cultural congruency to science. Costa categorizes students as: potential scientists, other smart kids, 'I don't know' students, outsiders, and inside outsiders (in Aikenhead, 1996, p. 16). While these designations of student potential in science learning seem deterministic, Aikenhead redirects the focus toward teachers. He emphasizes the need for teachers to maintain shifting roles as tour-guides to provide students with appropriate levels of support in border-crossings. In this way, students would be encouraged to navigate and transcend beyond their designated categories. In this sense, given teacher support, these borders would be softened into boundaries.

Given support, border crossings may become accessible to students with worldviews that differ from those of science. Though border crossings may be facilitated through instruction, it is unrealistic to expect that all students will cross cultural borders to fully engage in the sphere of science. Jegede and Aikenhead (1999) describe collateral learning, or where “conflicting schemata [related to science learning are] held simultaneously in long term memory” (p. 52). Rather than undergoing enculturation and assimilating to views of science, collateral learners adapt different responses to the cognitive challenges of border-crossing in science. These learners engage in science learning through anthropological approaches, where science is studied but may or may not be incorporated into prior-held cultural ways of thinking. Alternatively, students may undergo autonomous acculturation, where scientific and cultural ways of thinking coexist and are not disputed. In either case, a negotiation of cultural identity does not become part of the process of science learning. Identity and science learning remain separated. Moreover, students do not cope with challenges to cultural understandings by actively resisting science learning in these scenarios.

Building on Jegede and Aikenhead’s work, Fakudze (2004) considers border crossings into science from a non-scientific worldview. In her cognitive border learning crossing model, Fakudze offers further considerations of the positionality of scientific ways of knowing in relation to cultural beliefs and traditional ecological knowledge. Rather than focusing on crossing borders or boundaries, these perspectives on science learning assume parallel pathways and a “both/and” approach to epistemic differences. As described above, Lipka’s (1998) work with Yup’ik natives in Alaska provides a useful example of the successful application of cultural knowledge to science learning through inquiry as an alternative to an “either/or” approach that separates science learning from cultural understandings. Drawing on

cultural ways of knowing from community elders, teachers involved in the Cuilistet project were able to integrate science learning with traditional knowledge. This “both/and” approach of using traditional knowledge to structure science learning provided students with scaffolded science learning that acknowledged and integrated their cultural understandings.

Fakudze (2004) also suggests adapting science instruction to the cultural understandings of students:

There seems to be a need for a science curriculum that would require a science education perspective that views science learning as a process of crossing the boundary between the students’ worldview and science worldview.... this type of curriculum approach requires teachers to understand the students’ fundamental, culturally based beliefs so as to teach a kind of science that coincides with the intellectual interest and socio-cultural setting of such students. (p. 277)

In this way, a culturally congruent form of science would be taught. While this instructional approach may be effective in instructional settings serving a group of students that share culturally based beliefs, many underrepresented and ELL students participate in diverse and multicultural classroom communities. In diverse settings, it is not possible to find one particular *kind of science* that would be culturally congruent for all students. Lipka’s work was also limited to working between one group of underrepresented students and mainstream school culture. An application of Lipka’s work to an urban multicultural school setting would require significant considerations about how to draw on multiple worldviews in relation to science learning.

#### *Drawing from students’ home and everyday ways of knowing*

Some sociocultural perspectives direct greater attention to how the cultural backgrounds of students (Gonzalez et al., 2005) and components of schooling (Foley, 1990) may be implicated in the science learning process. Gonzalez et al. (2005) offer

conceptions that consider the cultural and community forces that shape students and the tools they use to learn. They revisit Vygotsky to reflect upon the “cultural tools and practices....[which] are always implicated in how one thinks and develops” (p. 18) as related to students and their experiences outside of school. They turn to participatory ethnography and anthropological theory to consider the life-worlds, or everyday lives, of students and the cultural tools that are part of their home-based practices. These cultural resources as referred to as funds of knowledge and are “generated through the social and labor history of families and communicated to others through the activities that constitute household life, including through the formation of social networks that are central to any household’s functioning within its particular environments” (p. 18). The researchers also consider the classroom as a cultural setting in and of itself, with its own cultural resources and practices.

Validated household knowledge implies a shift toward viewing students’ everyday understanding from a constructivist perspective. Students come to school with knowledge and experiences that are implicated in their day to day lives. Teachers can use these experiences in the context of school to support student learning. The researchers extend this relationship to science learning, or systematic learning in their words. Gonzalez et al. suggest that everyday knowing shapes and informs science learning and vice-versa. “The reciprocal relation between everyday and scientific concepts... and how they mediate each other” (p. 260) brings them to the conclusion that:

While everyday concepts provide the building blocks for the development of schooled concepts, they can be transformed through a connection with the academic. Similarly, scientific concepts can be transformed into the everyday, into the domain of practice, acquiring meaning and significance but also enabling conscious reflection and meta-awareness.” (p. 267)

A funds of knowledge perspective thus positions the learner in a reciprocal relationship with science learning. This perspective emphasizes the life-world and cultural understandings of the student as the point of departure for subject-matter learning in science. For example, rather than focusing on introducing and acculturating the student to science, a funds of knowledge instructional approach would focus on recognizing students' already existing background understandings about science.

This approach also aligns with conceptions of cultural congruency in instruction as described above. In a culturally congruent instructional approach, “teachers integrate academic disciplines with students’ linguistic and cultural experiences to promote academic achievement” (Lee & Fradd, 1998, p. 66). Moreover, it supports IC approaches to science education, where subject area instruction is combined with a “consideration of students’ cultural and linguistic experiences with attention to the specific demands of academic disciplines” (Lee, 2002, p. 67). As described above, IC entails creating the space for the interrogation of science and its constructs. For example, it could include a consideration of the elements of Western modern science that may not be compatible with some students’ ways of knowing and understanding.

The perspective that Gonzalez et al. (2005) offer is useful for considering the cultural backgrounds of students involved in science learning. Moreover, it recognizes both the embedded nature and hybridity of practice, where “human beings and their social worlds are inseparable... [and] human thinking is [thus] irreducible to individual properties and traits ... [and] always mediated, distributed among persons, artifacts, activities, and settings” (p. 266). In its applied form, the funds of knowledge approach calls for recognizing the cultural and community strengths of students from backgrounds that are underrepresented in the science and bringing them into the

classroom. Addressing cultural difference and students' home and everyday understandings as a part of instruction may thus provide students with support in mediating understandings about science.

An example of instruction drawing from students' everyday life understandings and funds of knowledge is described in Roth and Calabrese Barton's (2004) work. The researchers demonstrated how learning environments may be structured to connect students' life-worlds and science learning. While Calabrese Barton describes how homeless students engaged in science learning in an informal afterschool program at their shelter, Roth recounts how students participated in the activities of science in their local communities. The researchers emphasize how students were able to make science applicable to their lives and through this process, learn science content and appropriate scientific discourse. For example, students at the shelter were able to design and build tables as well as participate in nurturing the development of a garden in a reclaimed abandoned lot. Relevancy of science learning was established for students when their work contributed to community-driven efforts for watershed restoration. In both cases, participating in the processes of science in authentic and relevant settings fostered border-crossings into science. Through this approach, the divisions between students' life-worlds and science were reduced. Consequently, student identity did not stand as challenged by participation in science. The researchers would advocate for adopting some of the principles of informal learning into school-based settings. This would include a more student-centered approach to science instruction. The implementation of student-driven inquiry-based investigations could serve to meet this end.

This approach aligns with Kris Gutierrez's recent discussion about her informal science teaching experiences in an afterschool setting with Latino ELL students (March, 2007, Cornell University). Beyond science learning, she described



the complex and dynamic nature of cultural exchange in educational settings. Gutierrez emphasized the importance of avoiding a prescription of instructional approaches based on culture. Lipka et al. (1998) also point to the potential that interaction between cultures and communities creates for supporting underrepresented students in science learning. Instead of viewing cultural differences as stagnant and permanent, the researchers propose viewing culture as constantly evolving and adapting. They describe the “zone of the possible” as the point of intersection between cultures, or a third cultural reality (p. 24, 31). Instead of simply accepting or rejecting another way of knowing, the Ciulistet approach to pedagogy is to encourage negotiation between differing views.

Stairs (in Lipka et al., 1998) explains, a “cultural negotiation perspective redefines education as culture-in-the-making at multiple levels” (p. 31). This view of learning suggests that only continued interaction between communities affords the opportunity for learning. The intersection of students’ ways of knowing with the culture of science afforded through inquiry-based approaches provide students with opportunities for negotiating scientific understandings and science learning in the space of schools. However, in order to bring about cultural negotiation, the culture of science must also be made evident. This is further described below.

#### *Making science explicit as a part of negotiating cultural difference*

Lee (2003) suggests *explicit instruction* as a pathway towards boundary and border crossings in science education. She insists “ELL students need explicit guidance to recognize how their linguistic and cultural experiences may be continuous or discontinuous with the nature and practice of Western science.” A basic tenet of multicultural education, explicit instruction draws students’ attention to code-switching. For example, instruction toward recognizing the shift between everyday

language and scientific discourse would help make linguistic codes explicit. In this way, students would be supported in recognizing everyday language apart from scientific discourse towards crossing a boundary into science and learning when to use scientific language.

Lee also considers the value explicit instruction may have in mediating between the cultural experiences of students and the nature and practice of Western science. Engaging students in scientific activities and teaching about nature of science (NOS), or the epistemology of science, may help make borders to science evident so that they can be negotiated and crossed. Instruction toward understanding the nature and practice of science would entail inquiry-based instruction coupled with explicit instruction in NOS<sup>3</sup> (Lederman, 2004).

Though both traditional and alternative forms of science instruction in schools are implicated in learning Western modern science, border-crossings into science may be supported by engaging students in inquiry-based approaches to learning. Because activity reflects the cultural practices of a community, an inquiry approach using an authentic investigation could immerse students in scientific culture. Inquiry would thus afford greater opportunities for the negotiation of epistemic stances and worldviews as related to Western modern science.

A study by Krugly-Smolska (1995) provides encouragement for the use of inquiry-based instruction towards providing diverse ELL students in urban schools opportunities to negotiate cultural understandings. The researcher investigated methods of instruction that supported minority and ethnic student achievement in science at a school. The researcher observed that students were presented with scientific information where the “transmission of knowledge remained ‘top down’

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<sup>3</sup> Explicit instruction in NOS is viewed as both content-matter and an instructional approach. This study makes use of NOS as an instructional approach.

[and] students had little control over the progress and content of lessons and little opportunity to construct meaning for themselves” (p. 49) in traditional settings. This instructional approach did not provide students with the space to negotiate cultural differences or disparate understandings of science. Though the impacts of alternative instructional methods on student achievement in science remain inconclusive, underrepresented student groups demonstrated difficulties accepting the scientific “truths” as presented through traditional instruction. Inquiry-based investigation provided greater opportunities for negotiating understandings.

Nonetheless, the negotiation of multicultural and scientific understandings cannot be accomplished by inquiry alone. Instructional congruency considers how to increase the accessibility of science content matter; however, in order for the negotiation between understandings to occur, the properties and epistemological assumptions of science need to be made explicit. Southerland (2000) advocates for an instructional approach that “represents science as a form of human understanding, as a useful, fundamentally rational, but also limited, enterprise” (p. 300) as a form of multicultural education in science. Explicit instruction in NOS may serve to meet this end and provide an instructional approach to support both inquiry and multicultural instruction.

Lederman (2004) suggests bolstering inquiry-based science instruction with explicit instruction in NOS, which he describes as “the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge” (p. 303). Features of NOS include that:

Scientific knowledge is tentative (subject to change), empirically-based (based on and/or derived at least partially from observations of the natural world), subjective (theory-laden, involves individual or group interpretation), necessarily involves human inference, imagination, and creativity (involves the invention of explanations), and is socially and

culturally embedded (influenced by the society/culture in which science is practiced). Two additional important aspects are the distinction between observations and inferences, and the functions of, and relationships between, scientific theories and laws. (p. 304)

Framing science within its epistemological assumptions would provide students with tools for the exploration of science on its own terms and provide an avenue for not only expanding the definitions of science, but also recognizing its limitations (Southerland, 2000). Southerland further describes, “by helping students understand the epistemological foundations of science in comparison of other systems of thought, we recognize and build upon students' agency in the learning process” (2000, p. 300). Rather than implementing science instruction that challenges, marginalizes, and is “subtractive” to students’ epistemic stances and worldviews, greater IC can be met with instructional approaches that provide opportunities for experiencing and demystifying science.

### ***An Instructional Approach Combining Inquiry, IC, and NOS***

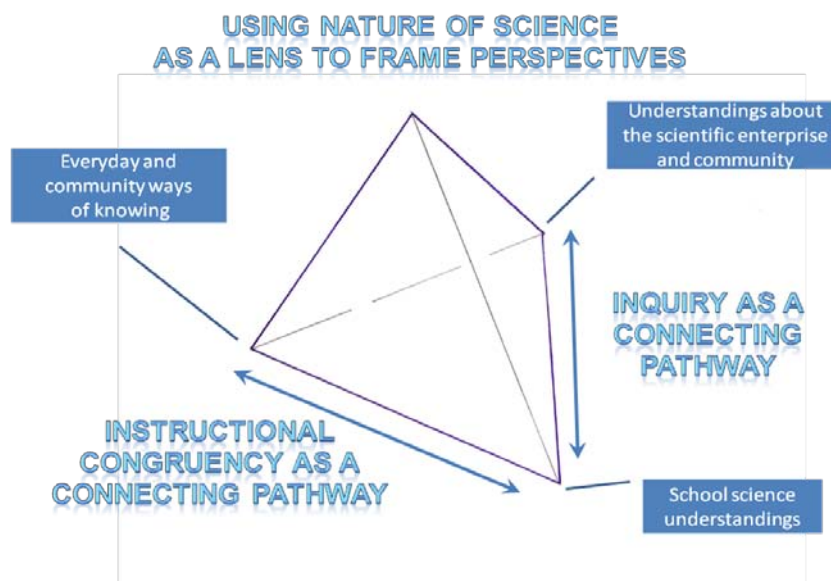
Inquiry, combined with IC and explicit instruction in NOS provides a promising instructional approach for reaching underrepresented and ELL students with culturally relevant and accessible instruction in science. The following section draws from the research and theory above to propose a theoretical model that utilizes inquiry, IC, and NOS as its constructs. Each of these three constructs have different focal points that when brought together may enhance science learning environments for students. For example, inquiry engages students in the activities of science. However, it may not do enough to explain how those activities are framed by scientific culture. Further, IC focuses on the accessibility of science based on the cultural backgrounds of students; however, not the cultural aspects of science. And, while instruction in NOS (Lederman, 2004) may help demystify scientific culture, by itself it does little to address how to connect scientific culture to students’ cultural understandings.

Inquiry and IC, and inquiry and explicit instruction in NOS, have been grouped together as instructional approaches previously; however, all three have not yet been merged in theory or practice. Inquiry combined with both IC and explicit instruction in NOS could provide opportunities for students to engage in the activities of science, while taking the culture of students and science into account. Whereas IC may facilitate the inclusion of students' diverse cultural understandings in classroom science learning, explicit instruction in NOS may facilitate greater explication of the cultural components of science. Together, these approaches complement one another in that they address the explicitness of instruction, a multicultural tenet, and provide a space to acknowledge and address cultural differences.

Interestingly, overlap exists between the features of the inquiry, IC, and NOS constructs. For example, IC aligns with inquiry based approaches, in that it is a student-centered instructional approach and involves a sharing of authority. Most notably, however, there are features of these constructs that have not yet been combined and may serve to bolster one another. For example, while inquiry engages students in the activities of science, explicit instruction in NOS may better help frame these activities in relation to the assumptions of science. This would include considering the social and cultural embeddedness of scientific knowledge (NOS) and the diversity of students' cultural experiences (IC) when connecting inquiry-based explanations to scientific knowledge. Instructional congruency can be extended to include explicit instruction in NOS as a multicultural approach in that it addresses other important cultural components of science, such as scientific knowledge being socially constructed and subjective.

An instructional emphasis on NOS may facilitate students' abilities to navigate between their own understandings, school science, and the scientific enterprise (see Figure 1 below). IC, for example, makes use of linguistic scaffolding to increase the

accessibility of science during instruction. This approach, combined with NOS, would also frame school-based inquiry in relation to the culture, norms, and assumptions of science. Explicit instruction in NOS offers a pathway for explaining how science influences day-to-day life and its potential limitations. School-based inquiry offers an instructional approach to begin to bridge between school science and the activities, context, and culture of the scientific enterprise. The possibilities and limitations of these scientific ways of knowing can be introduced to students in classroom settings through explicit instruction in NOS.



**Figure 1. Inquiry and IC in Science framed by NOS**

Together, instructionally congruent inquiry-based instruction combined with explicit instruction in NOS may provide important opportunities for underrepresented students in negotiating differences between their lifeworlds, school science, and the scientific enterprise. Along the lines of collateral learning theory, where learners may hold and negotiate between multiple understandings (Jegede & Aikenhead, 1999), and

a “both/and” instructional approach (Lipka, Mohatt, and Ciulistet Group, 1998), this combined approach does not seek to challenge students’ cultural ways of knowing, but rather, provide tools for better understanding science on its own terms. Because limited research has been directed toward the implementation of instructional approaches to support underrepresented students in mediating between cultural understandings and science, a classroom attempting to utilize the instructional approach using inquiry combined with NOS provided a context in which to investigate how this approach may be enacted in a classroom serving students from underrepresented backgrounds. The implementation of Fossil Finders, a curriculum designed to make use of inquiry and NOS, in a middle school classroom with a teacher already using IC strategies to serve diverse students provides the context for investigating this combined instructional approach.

### ***Summary***

Taken together, the reviewed studies suggest that supporting students in making linguistic and cultural boundary and border-crossings in science learning would include recognizing science as a cultural way of knowing, adopting IC learning strategies, and demystifying science through inquiry and explicit instruction in NOS. While inquiry-based approaches afford opportunity for establishing greater relevancy in learning experiences, instructionally congruent inquiry coupled with explicit guidance in NOS may help frame science as cultural way of knowing and provide students with opportunities to negotiate identities in relation to science. Combining these instructional approaches may provide promise and possibility for reaching students in science education, and underrepresented student groups, in particular.

Currently, research studies demonstrate positive findings related to the use of inquiry with underrepresented students. However, this research is limited to focusing

on mostly lower level elementary-school students (Amaral et al., 2001; Cuevas et al., 2005; Lee et al., 2005; Lee et al., 2006) and the appropriation of scientific discourse and English language learning (Rosebery et al., 1992; Stoddart et al., 2000; Warren et al., 2001). Further research is needed in the area of culturally congruent inquiry-based instruction with upper level middle school and high school underrepresented and ELL students. This would include greater consideration for the diverse home and cultural understandings that students may bring to multicultural classrooms (Gonzalez et al., 2005) and how these understandings are applied to science learning.

Moreover, while researchers provide theoretical constructs for considering science as culture and science learning as a cultural border-crossing (Aikenhead, 1998; Jegede & Aikenhead, 1999; Lipka et al., 1998), research conducted in this area mostly entails underrepresented students from similar cultural backgrounds. Further research is needed to investigate how to provide students from diverse cultural backgrounds in multicultural classrooms support in science. This would include researching how explicit instruction in NOS may afford underrepresented and ELL student groups greater connections to science learning. While explicit instruction in NOS coupled with culturally congruent inquiry-based instruction may provide students with a means to negotiate understandings in science, there is currently no empirical evidence related to the use of this instructional approach with underrepresented students.

The context of the Fossil Finders investigation in a classroom serving underrepresented students provided the grounds to investigate the implementation of an instructional approach combining inquiry, IC, and explicit instruction in NOS, as well as students' responses to it. The next section will describe the methods used in this study.



## **CHAPTER 3**

### **METHODS**

The theory presented in the literature review section makes the case for an integrated instructional approach combining inquiry, IC, and explicit instruction in NOS to engage underrepresented students in science. Making IC and NOS an explicit and integral part of inquiry-based science teaching may encourage underrepresented and ELL students to participate in the activities of science. Further, students may be supported in crossing boundaries and borders between personal ways of knowing, school learning, and the scientific enterprise. This approach may also bridge the extant gap between home and school-based science cultural understandings.

The implementation of an instructional approach combining inquiry, IC, and NOS in an urban middle-school classroom provided an opportunity to investigate the nature of instruction and how students respond to this combined instructional approach. To this end, a case study approach (Merriam, 1988; Yin, 1984/1989) was used to address the research questions driving this investigation: (1) How does the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach, and (2) how do underrepresented students experience and respond to an instructional approach combining inquiry, instructional congruency and explicit instruction in NOS?

The rationale for focusing on the teacher was to gain a better understanding of how the instructional unit is actually implemented, while focusing on the students was necessary to learn how they experience and respond to learning about science through this instructional approach (Calabrese Barton, 2003). The research question

addressing the teacher's implementation of the curriculum was divided into sub-questions that focus on each of the guiding constructs separately:

- a) In what ways does the teacher make NOS explicit to students during instruction?
- b) In what ways does the teacher engage students in inquiry?
- c) To what extent does the teacher use instructionally congruent strategies in teaching science?
- d) How are inquiry, IC, and explicit instruction in NOS brought together in this teacher's classroom?

The research question addressing students' experiences in this classroom was also subdivided to focus on each of the guiding constructs. With the exception of one question focused on student learning, these sub-questions parallel the sub-questions related to their teacher's instructional approach (see Table 1). These sub-questions asked:

- a) In what ways do students engage in scientific inquiry?
- b) How do students bridge everyday understandings and science in the space of inquiry?
- c) What are students' views of NOS and how do these change during the investigation?
- d) How are students supported in content-area learning?

These questions were grounded in the implementation of the Fossil Finders investigation in an urban middle-school classroom serving ELL students from Latino backgrounds. Both the Fossil Finders curriculum and the instructional setting are described below in the next section.

## ***Instructional Background***

### *The Fossil Finders Curriculum Unit and Investigation*

The Fossil Finders project is a collaborative initiative between Cornell University's Department of Education and the Paleontological Research Institute (PRI) funded by the National Science Foundation (NSF). The project aims to develop curriculum and resources for teaching evolutionary concepts through an authentic inquiry-based investigation using fossils. The project's three driving goals are as follows:

*The primary goal* is to create an authentic context to enhance children's and teachers' understandings of the nature of science (NOS) and evolutionary concepts. *A second goal* is to motivate children to learn more about science, including culturally and linguistically diverse groups of children. *Our third goal* is the development of educational materials that help teachers and children understand inquiry. (Crawford, Ross, & Allmon, 2007, p. 1)

To this end, a group of ten teachers participated in a summer professional development program focused on NOS, evolutionary concepts, inquiry, and conducting paleontological research during the summer of 2008. During this week-long summer session, teachers worked with educational researchers to learn about inquiry, NOS, and culturally relevant teaching. Teacher professional development using an activity-based approach has demonstrated success for elementary school teachers (Akerson, Abd-El-Khalick, Lederman, 2000). Though understandings about NOS and inquiry may not directly translate to enacting these instructional approaches in classroom settings (Akerson & Abd-El-Khalick, 2003; Schwartz & Lederman, 2002), these teachers were better prepared to engage their students using these curricular approaches through the context of the Fossil Finders curriculum, as described below.

Teachers also interacted with both scientists and educational researchers to collaboratively conduct geological fieldwork related to the scientists' research. The educational researchers modeled activities that focused on inquiry and NOS for teachers to use in their classrooms, and they introduced the Fossil Finders curriculum unit (Appendix L). This curriculum was in its pilot phases and the Fossil Finders project team requested feedback from teachers based on its implementation their classrooms. The implementation of the Fossil Finders curriculum in classrooms would involve students in the authentic investigation their teachers experienced over the summer. By implementing lessons in the Fossil Finders curriculum with their classrooms, teachers thereby involved their students in the research project. The Fossil Finders curriculum unit and investigation are described in further detail below.

#### The Fossil Finders Curriculum Unit

The Fossil Finders curriculum unit is structured around the National Academy of Sciences (NAS) targeted standards for the instruction of evolution and nature of science for students at the 5<sup>th</sup> through 8<sup>th</sup> grade levels and literature about learning progressions in evolutionary concepts (Catley, Lehrer, & Reiser, 2005). In the document *Teaching about Evolution and the Nature of Science* (NAS, 1998), specific National Science Education Standards (NSES)(NRC, 1996) were selected to support student conceptual learning about NOS and evolution at various grade levels. These targeted standards are drawn from the areas of *Life Science*, *Earth and Space Sciences*, and *History and Nature of Science*. These standards include: 1) Reproduction and heredity; 2) Diversity and adaptation of organisms; 3) Earth's history; 4) Nature of science; and 5) History of Science (see Appendix M). The curriculum unit was developed during spring 2008 and includes background instruction in evolution, environmental change, and NOS. These background lessons feed into the cornerstone

of the curriculum, the Fossil Finders Investigation (described below). The Fossil Finders curriculum unit was also developed to draw on students' cultural understandings and support students with varying language abilities during instruction with vocabulary-building activities. Instructional approaches fostering IC and the inclusion of funds of knowledge, such as linguistic scaffolding and the use of journaling, were integrated into the curriculum design. The Fossil Finders curriculum also was also developed to encourage classroom fieldtrips to outcrop sites or local natural history museums to supplement the curriculum and virtual visits through the project website.

#### The Fossil Finders Investigation: An Authentic Scientific Research Project

The Fossil Finders Investigation is an authentic scientific research project that involves students in the work of paleontologists focused on addressing the question: *Do the animals in the shallow Devonian sea stay the same during environmental changes?* To this end, students collaborate in fossil identification and measurement toward compiling a data set in collaboration with other classrooms and scientists from a museum of paleontology. The idea presented to students is that scientists' need help in identifying and gathering measurements of samples of fossils from the Devonian period. With student help, both students and scientist may benefit (Shirk, *in revision*). Through this mutualistic relationship, students may learn about the nature of scientific inquiry and geological content-matter while scientists are enabled to move forward with their work. Further, students' science learning would occur through interacting with scientists within a context that is authentic to scientific activities. This aligns with the tenets of participation in a CoP. In order to implement this project:

Stratigraphically-constrained samples of layers of shale from an Upstate New York outcrop [were] shipped to a range of classrooms (urban and rural) in the New York State and to schools across the

country. The intent is to actively engage children (and teachers) in 5th/6th and 7th/8<sup>th</sup> grades in the use of evidence in constructing explanations of natural phenomena. Classrooms who join the *Fossil Finders* project... compare[d] their identification of fossils with museum based specimens. (Crawford et al., 2007, p. 1)

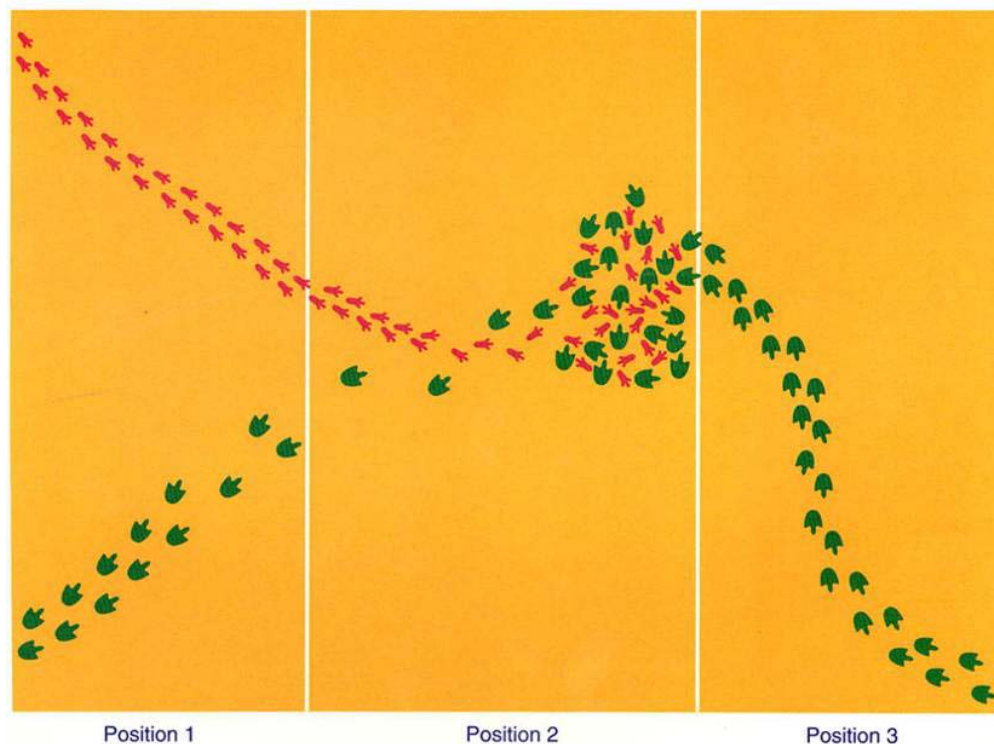
Together with educational researchers from Cornell Department of Education, scientists from the paleontological museum provided teachers and students with resources and online support for fossil identification. Project staff and scientists also provided classroom teachers assistance with answering questions using the project website and fielding digital photographs of samples difficult to identify.

As a part of the investigation, students identify and measure fossils, and enter their data into online database. Data is then compiled in conjunction with other classrooms involved in the project. Using the database, students may then investigate “how marine invertebrate assemblages have responded to environmental changes in the past” and learn to use evidence in constructing explanations of the geological past (Harnick & Ross, 2003). To date, most instruction in the area of geological and evolutionary concepts occurs through the use of textbooks, worksheets, and stimulation labs. Because these traditional activities do not model the activities of scientists in the field, the Fossil Finders project serves as a point of departure from traditional instruction in evolutionary concepts.

The Fossil Finders curriculum background instruction also includes an introduction to the concepts of NOS. The “Proposing Explanations for Fossil Footprints” activity (NAS, 1998), which I refer to as “Tricky Tracks,” is used toward this end (see Appendix M for lesson). In this activity, the teacher uncovers section by section of unidentified tracks (Figure 2), while students make observations and inferences about what must have occurred.

The teacher is able to use this example to illustrate how scientists may have differing ideas, despite the same data, and how these ideas may change based on the

availability of more information. In this way, this activity provides teachers with the grounds to address various features of NOS, such as the tentative nature of scientific knowledge and the social construction of explanations. The implementation of this activity in a middle school classroom thus provided the context to investigate how an instructional approach combining inquiry, IC, and explicit instruction in NOS<sup>4</sup> may play out in a classroom focusing on these constructs.



**Figure 2. Tricky Tracks Visual Slide (NAS, 1998)**

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<sup>4</sup> One of the features of NOS includes the difference between a theory and a law. This concept was not emphasized in the Fossil Finders unit through the Tricky Tracks activity and is thus not addressed in the scope of this study.

### Engaging Underrepresented Students in Science

While the Fossil Finders project aims to reach all students, it focuses on students underrepresented in the sciences, in particular. This includes “English language learners... and children whose race and gender are not generally well represented in the sciences” (Crawford et al., 2007, p. 2). The curriculum developed for the project (described above) includes explicit instruction in NOS, entails elements of language learning support and IC (Lee & Fradd, 1998), and embeds home and community connections into the project (Gonzalez, Moll, & Amanti, 2005). Theoretical support for the inclusion of these instructional approaches with underrepresented students is described in the literature review.

Through participation in a research investigation, students are presented with opportunities to contextualize science learning within practice of scientific research and engage in the activities of the scientific community. The Fossil Finders project initiative thus provides the setting to address the guiding question of this research and address how involvement in inquiry, infused with instructionally congruent practice and combined with explicit instruction in NOS may support underrepresented and ELL students engage in and learn about science.

### ***Instructional Setting and Research Subjects***

The ten teachers participating in the 2008 Fossil Finders summer professional development program were selected based on their years of teaching experience, science background, proximity to the university, motivation to participate, and the demographics of the students they serve. Of these ten teachers, Monica, the focus teacher of this case study, was purposefully selected, because of the high number of underrepresented and ELL students she serves. This study focused on Monica’s



implementation of the Fossil Finders instructional unit and how her students responded to her instructional approach.

Monica is a 5<sup>th</sup> grade teacher in her 6<sup>th</sup> year of teaching who was interested in providing greater amounts of science instruction to her students. Though Monica is an experienced elementary level teacher, she is a novice at teaching science in her classroom. In this way, Monica's background is representative of elementary and middle school science teachers attempting to teach science. Like many elementary and middle school teachers, Monica received a multi-subject teaching credential and though she is interested in teaching science to her students, has little academic preparation for doing so. Monica nevertheless maintained an interest in science, and geology in particular, and attended multiple district-wide professional development sessions focused on science instruction. Some of these professional development experiences focused on inquiry-based instruction. However, at the start of the project Monica was not entirely confident about her capabilities to teach science, according to her application to the Fossil Finders professional development program, where she wrote:

At this time I am still uneasy about teaching science... I enjoy reading about new scientific discoveries; I regularly watch the Discovery and Animal cable channels, too... my strengths in science instruction lie in reading and writing. My weakness is implementation of experiments.

In her application, she also wrote, "I hope to become a better science teacher for my students." Thus, it is evident that Monica's interest in teaching science by implementing inquiry was partly derived from her intention to provide better instruction to her students. Monica thus represented a unique case of an urban middle-school teacher with little preparation in science seeking to provide inquiry based instruction to underrepresented students.

Monica's bilingual background and instructional practices focused on reaching ELL students prepared her to implement inquiry combined with IC in her classroom. Monica is a native Spanish speaker and is part of a dual-language program at her school, where she co-teaches her class with another teacher, Miss Solis. While Miss Solis focuses on math and history instruction, Monica provides reading and science instruction. Further, like many of her students, Monica and her family come from Puerto Rico. Thus, she is able to share common cultural references with her students during instruction. Because this research study focused on how a combined instructional approach between inquiry, IC, and NOS may assist underrepresented students in science learning, this teacher's implementation of the Fossil Finders curriculum created an opportunity to observe both how this instructional approach may play out in a classroom setting and how students from underrepresented background may respond.

The middle school in which Monica teaches is situated in an urban area of Upstate New York. At the time of this research, Monica's school building was undergoing reconstruction and the entire school was temporarily relocated to a reclaimed factory building. Monica's 5<sup>th</sup> grade classroom had enough space to line two rows of desks, face to face to accommodate her 18 students. Her room contained a reading rug and a desk for both Monica and Ms. Solis. The classroom also contained a sink, but was limited from other set-up typically needed for science instruction.

Monica's school serves diverse students from kindergarten through sixth grade, with 68 percent of the students being Black and 26 percent of the students from Latino backgrounds. Of these students, 10 percent of the student-body consists of ELL students. Monica's class, observed during this study, was non-representative of the overall demographics at the school in that all 18 of her students were ELL students

from Latino backgrounds with varying degrees of ELP (see Table 2). While some students were recent immigrants from Puerto Rico, others came from families with mixed cultural backgrounds. These students participated in the dual-language program at their parents' request or based on their levels of ELP.

**Table 2. School Demographic Settings**

Teacher	Grade-level	Years of Teaching Experience	FRPL- (SES indicator)	ELL students (%)	Latino Students (%)	Black Students (%)
Monica	5	6	84	10	26	68

Of Monica's 18 students, a group of 10 were receiving specialized language instruction based on lower and developing levels of ELP. These students were withdrawn from class for language instruction in the hallway while the other group of eight students remained in class. Focus students from both of these groups were selected for interviews and a more detailed analysis of student work and for interviewing from each of these groups in order to maintain representation of differing levels of ELP.

During the implementation of the Fossil Finders project, I conducted broad observations in this class. However, I paid particular attention to the five focus students. Focus students consisted of one girl and one boy with lower levels of ELP (Alyssa and Brandon), and two girls and one boy with higher levels of ELP (Bianca, Paula, and Raul). Students were selected from different levels of ELP to maintain better representation of the classroom diversity. Also, because students with lower levels of ELP were called out of science instruction for specialized language instruction, selecting focus students from both groups would provide better data with respect to student learning in each representative group. Further, students were

selected from both gender groups in order to gather information on student views of science from both girls' and boys' perspectives. However, given the underrepresented nature of women in science, an additional girl was selected as a focus student to obtain more data on Latina girls' perspectives on science in particular. These students and their parents were interviewed in-depth on their views on scientific inquiry, NOS, and how cultural funds of knowledge were brought into science learning as a part of the research design, which is described below.

### ***Research Design***

As described above, a case study approach (Merriam, 1988; Yin, 1984/1989) was used in this research to focus on Monica's instructional implementation of the Fossil Finders unit and the embedded constructs of inquiry, IC, and explicit instruction in NOS, as well as her students' response to this instruction. The unit of analysis was the classroom, in which Monica implemented the Fossil Finders unit over the course of 13 instructional days, starting in late September through mid-December, 2008. Classroom observations were conducted in Monica's classroom during the instructional implementation of the unit with a two-part focus. Data collection related to the *classroom context and the nature of instruction* included fieldnotes during classroom observation and video-taping. Data collected related to investigating *students' experiences in a classroom using this instructional approach* included: fieldnotes during classroom observations (as described above), student work samples, pre-post assessments measuring content-matter understandings, understandings about inquiry, and NOS (Lederman, Abd-El-Khalick, & Schwartz, 2002), and interviews with focus students and their family members. Interviews were conducted to gather greater information about how students and their family members viewed NOS and the scientific process. Table 3 illustrates the research approach used in this study.

**Table 3. Overview of Research Design**

Research Question		
<b>1) How did the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach?</b>		
	Data Source	Data Analysis
a) In what ways does the teacher engage students in inquiry?	Classroom Observations (fieldnotes, videotaping)	Content analysis using standards for inquiry (NRC, 2000).
b) To what extent does the teacher use instructionally congruent strategies for teaching science?	Classroom Observations (fieldnotes, videotaping)	Content analysis using Lyukx & Lee (2007) framework for instructional congruence.
c) In what ways does the teacher make NOS explicit to students during instruction?	Classroom Observations (fieldnotes, videotaping)	Content analysis using Lederman (2004) features of NOS.
<b>2) How did underrepresented students experience and respond to an instructional approach combining inquiry, IC, and explicit instruction in NOS?</b>		
	Data Source	Data Analysis
a) In what ways do students engage in scientific inquiry?	Classroom Observations (fieldnotes, videotaping) of students' informal conversations, body languages, activities; Student work samples; Interviews with focus students	Transcription of video and audio recordings and selected sequences of incidents of inquiry; Content analysis of transcriptions and fieldnotes using standards for inquiry (NRC, 2000);
b) How do students bridge their everyday knowledge and science in the space of inquiry?	Classroom Observations (fieldnotes, videotaping) of students' informal conversations, body languages, activities; Student work samples; Interviews with focus students and student family members	Transcription of video and audio recordings and selected sequences of incidents of students bridging between home, school, and scientific understandings; Content analysis of fieldnotes and transcripts.

<b>Table 3 (Continued)</b>		
c) What are students' views of NOS and how do these change during the investigation?	Classroom Observations (fieldnotes, videotaping) of students engaging in NOS activities; Pre-post-post assessment (including VNOS-E questions); Interviews with focus students and student family members	Transcription of video and audio recordings and selected sequences of incidents of students engaging in features of NOS; Content analysis of fieldnotes and transcripts. Content analysis of pre-post-post assessment
d) How are students supported in content-area learning?	Classroom Observations (fieldnotes, videotaping); Pre-post assessment (including questions related to geology, environmental change, and evolutionary concepts); Student work samples; Focus student interviews	Comparative analysis of video data for student content-matter knowledge; Content analysis and simple statistics of pre-post concept-inventory; Content analysis of student work and interviews

Various methods of data collection were used to gather data with respect to the multiple focal points of this study, which include a consideration for science as a cultural way of knowing and students' cultural understandings about science. In some instances, multiple data points were gathered for the purposes of triangulating findings.

The above table illustrates the approach used for data collection and analysis. The following section will describe the rationale for methods of data collection and how data were gathered in greater detail.

### *Methods of Data Collection*

#### Classroom Observations and Videotaping

I videotaped classroom instruction and gathered fieldnotes throughout the duration of the instructional unit. Videotaping was used as a method of data collection

in order to capture the broad range of classroom activity during instruction. Jordan and Henderson (1995) describe videotaping as a useful “interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment” (p. 39). The rationale for using videotape data includes that it can be used to reconstruct classroom events, share primary data records, and capture the interactional complexities that may play out in classroom settings. Because video data provides a record of instruction, it provided material for analyzing how Monica made use of the focus constructs in her instructional approach (Crawford, Krajcik, & Marx, 1999). As a data record, video provides material for “grounding theories of knowledge and action in empirical evidence... and steadfastly holding our theories accountable to that evidence” (p. 41). In this sense, video data becomes fundamental evidence for addressing research questions and grounding interpretations in a record that can be reviewed.

During data collection, I set the video camera up on a tripod in the back of the classroom prior to the beginning of lessons related to the Fossil Finders unit. However, because of instructional variations, such as moving from large-group instruction to smaller group work, videotaping needed to occur from several angles within the classroom. During group work, the camera was placed in the center of the classroom and at times, I moved around the room with the camera to interview students about what they were doing. At other times, I assisted the teacher and students during the implementation of the unit (see section on the participant-observer role of the researcher below). During the times I was working with the teacher or students, video data was particularly useful for capturing other classroom interactions. See Appendix D for a more detailed account of video data collection in Monica’s classroom.

While the camera was stationary, I gathered fieldnotes about the classroom context, with specific attention to the implementation of the focus constructs. This included the instantiation of inquiry, IC, and explicit instruction in NOS, as well as student informal conversations, activities, body language, and work samples. After each class, I wrote content-logs of the instructional day and compared notes with the Luykx and Lee (2007) framework for IC (Appendix E). This framework offers a classroom observation tool that combines considerations for science learning and sociocultural difference. Though the framework is structured for large-scale observation studies, it provides a tool from which to quantify observations of culturally congruent science teaching practices. These include a teacher's use of: 1) scientific authority, 2) diversity of cultural experiences and materials, 3) students' home language in regular (non-bilingual) classrooms, and 4) linguistic scaffolding to enhance meaning, during classroom instruction.

### Interviews

I used interviewing as a method of data collection in order to obtain greater information on student views of science and NOS. Though pre-post measures were also gathered as data on student views of science and NOS (as described below), interviews provided opportunities for open-ended questions and for following up on student responses for greater clarification. Interviews for Spanish-speaking ELL students were conducted in English, Spanish, or bilingually. Because students had various levels of ELP, interviewing allowed me to rephrase questions for students when needed in both English and Spanish. Further, providing these language options, students could better help inform me about their views and experiences. This in turn helped eliminate misunderstandings between myself as a researcher and the students.



Interviews were conducted with the five focus students in the back of the classroom during class time on two occasions. The first interview used an interview script, in which I asked students a series of questions with respect to their views on science and how it may apply to their everyday lives (Appendix H). The second interview was conducted following a scientist's visit to the classroom. In this case interview questions pertained to how students' views on science may have changed following this visit. This interview also made use of a scripted series of questions (Appendix I). Together, these two interviews provided more detailed data on focus students' views on science. Further, during class, I informally asked random students about what they were seeing or what they were doing. This real-time feedback provided useful data on change in students' understandings about content matter and science. Fieldnotes and video also captured these changes.

I also conducted interviews with these focus students' family members (Appendix J). To this end, I visited students' homes, parents' places of work, and made phone calls to students' parents. These interviews were also conducted in English, Spanish, or bilingually. The purpose of these interviews was to gather data to better frame the home and cultural context of students and its possible influences on their views on science. These interviews provided important data on parents' views of learning and culture in and out of school settings.

### Assessment Measures

Students were tested on their understandings about inquiry, NOS, and geological content-matter prior to and after the instructional unit to gather information on how their views and learning may have been affected. The content assessments used in this study were compiled for the Fossil Finders project by the project team and the external evaluator, the Ohio Evaluation and Assessment Center for Mathematics and Science

Education (Ohio E & A). This assessment drew on other validated instruments measures, including the elementary school version of the Views on Nature of Science (VNOS-E) assessment (Lederman et al., 2002). The VNOS-E instrument is used to assess elementary students' understanding of NOS and has established reliability and validity. One of the assumptions of this research is that science content matter will become more accessible to underrepresented student groups through inquiry and explicit instruction in NOS. Therefore, it is important to assess students' understandings of the NOS science in relation to content-matter and the instructional approach used. Questions related to geological content-matter used a multiple-choice format, while questions related to views on NOS used a short-answer format. Because it is possible to evaluate multiple-choice responses in a quick and efficient manner, these data provide broad information about understandings in the classroom. While short-answer responses are more difficult to evaluate, they provide more in-depth information about student knowledge. The Fossil Finders project used this instrument in classrooms to evaluate the project. Because student learning is also part of student experience in a classroom, this assessment was used for the purposes of this research as well. Descriptive statistics were used to evaluate student responses to the multiple choice questions.

Monica implemented the assessment with her students as a pre-test prior to their involvement in the Fossil Finders project (mid-September). After completing the Fossil Finders curriculum unit, she implemented the same assessment again as a post-test (January). Because students had varying levels of ELP, Monica used language support methods of instruction and read the pre- and post- assessment questions out loud. This provided Spanish language support to students with questions arising due to their limitations in English. The VNOS-E was then implemented again in March as a post-post retention measure. Student responses on this measure provided another

data point for comparison to the questions included in the pre-post assessments. Results on the VNOS-E were compared to responses during open-ended interviews with focus students as a means of triangulating data.

### Student Work Samples

Student-generated work can be used as a measure of student involvement in classroom activities and a comparison of student work across time may indicate growth in learning. I gathered student work samples from the five focus students, which included photographs of journals, and copies of the Tricky Tracks and Rocks Tell Stories writing assignments. Student journals included note-taking during the Fossil Finders investigation and reflections on classroom activities. The Tricky Tracks stories illustrated how Monica and her students applied a literacy activity to NOS concepts. Finally, the Rocks Tell Stories assignment was completed outside the Fossil Finders curriculum unit; however, it demonstrates student use concepts from Fossil Finders.

### *Role of the Researcher*

I approached this research taking a participant-observer role. My background with the Fossil Finders project included initial involvement in the grant-writing, and later involvement in overall project planning, and curriculum development phases. As such, I am familiar with all aspects of the curriculum, and instructional adaptations for ELL students, in particular. In this way, I was able to provide Monica with support in implementing the curriculum when needed. While this project-based and curriculum knowledge was useful in assisting Monica, it may have also confounded my role as a researcher. It was not possible to assume a neutral role as a researcher in this classroom. Through my involvement with the Fossil Finders project, my relationship with Monica, for whom I served as a resource person and a collaborator in the Fossil

Finders project, was framed and reinforced during the summer professional development program, prior to collection of classroom data. However, I made a conscious effort to not intervene in Monica's implementation of the instructional approach in her classroom. This included only taking an active role to assist Monica with the curriculum at her own request and responding to questions when asked, rather than offering guidance or information. Nonetheless, it is fair to assume that my presence in the classroom was invariably tied with the implementation of the curriculum and exerted some influence on how the curriculum was enacted in this classroom.

### *Threats to Validity*

The case study design of this study with a participant-observer approach inherently induced threats its validity. It is not possible that my presence in the classroom would not in some way influence the teacher and her students. Additionally, my own biases in data collection will influence findings. In this section, I explain these threats in greater detail and how I address them in my research.

I attempted to reduce the influence my presence in the classroom would have on this study in variety of ways. Primarily, I needed to separate my role as a researcher from my role as part of the Fossil Finders staff. As described above, I made a conscious effort to maintain a neutral role in the classroom with participation when invited or called on. This separation of roles allowed me to focus on research questions and other observations. Further, my research in the classroom included bringing video equipment with me. To reduce student response to the camera, I began visiting the classroom prior to the start of the Fossil Finders instruction. Beyond accustoming students to the presence of a researcher with video equipment in the

classroom, the purposes of these visits included gathering an understanding of regular classroom instruction and building rapport and familiarity with students.

I began accustoming students to the presence of a video camera in the classroom by initially placing the camera in an unobtrusive location and gradually moving and shifting its location as students became more familiar with me and the camera. However, it is also important to consider bias in video data itself. As Jordan and Henderson (1995) describe, “the person operating the camera, by pointing the equipment at one object and not another, by adjusting from zoom to wide-angle views, by setting the audio level and so on, determines who or what is visible and audible and what is not. The camera operator's notions of what is significant and what is not invariably influence the kind of record he or she produces” (p. 53). In this sense, data gathered through video data is already biased, based on the perspective of the researcher and camera angle. At times that I interviewed students about what they were doing, I used a systematic approach of moving around the classroom to reduce bias in terms of which students I would interact with. However, in the act of videotaping particular students, other students were omitted from the video recording. Moreover, how the camera is set up and the moments it captures, as well as the theoretical lenses driving the research, also influenced data analysis. Hall (2000) explains, “technical and theoretical constraints drive towards creating data records that show just those parts of interaction we already find interesting and little more... judgments have a tendency to creep into both what we choose to record and how we watch it” (p.12).

The values that Hall (2000) describes may also play out in video data processing and transcription. For example, what the researcher chooses to transcribe or not are also driven by the theoretical and other lenses of the researcher. Threats to validity were reduced by focusing on the features of inquiry, IC, and NOS in data

analysis. For example, video content logs were coded for these constructs and then transcribed in segments having to do with them. This way, data were processed in a systematic way. Through this approach may have reduced bias in terms of transcribing certain segments in greater detail than others, which in turn may lead to a non-representative data set, this approach may have led to missing other potentially important findings.

Transcription itself also introduced biases, however. For example, certain video segments were more suitable for transcription than others based on the clarity of recordings. Thus, certain instructional moments were represented in transcriptions over others. This includes the examples of large-group instruction over the examples of student group work. Because the video recording clearly captured Monica's voice during instances of large group instruction, there are more transcriptions of this type of instruction. Group work recordings were more difficult to transcribe as a result of overlapping voices and inaudible speakers. Thus there were fewer amounts of transcribed materials having to do with group work. Again, fieldnotes could help address some gaps in data; however, these data limitations affect other analyses based on transcription data. As Jordan and Henderson also describe, "transcription not only leaves things out but actually does a special kind of violence to the spoken word. It fixates what is essentially fluid and ephemeral. It holds talk up for repeated inspection, the very impossibility of which is central to the lived experience" (p. 48). In order to reduce the impact of fixating on non-representative interactional instances, data from across the instructional unit was observed. Moreover, fieldnotes supplement transcriptions to contextualize these moments for a broader overview. Generally, these biases will continue to influence any sort of data collection with respect to video data and transcription. Consequently, readers must acknowledge the limitations of video data and transcriptions with respect to findings. Nonetheless, these data sources

provide a more complete record of classroom instruction and interactions than fieldnotes alone.

Other forms of data have also been influenced by the research process, such as interviewing. Because the process of conducting an interview involves interaction, the researcher participates in the interview. During this study, my verbal or non-verbal gestures, intonations, or responses to interviewees may have influenced their responses. To reduce these influences, an interview script was used. Further, focus students, or the subjects, were selected at differing genders and at differing levels of ELP to provide more representative data. Though these data may partially be influenced by the researcher in the interview process, they serve to triangulate other data, such as the assessment measures.

The assessment used in this study introduced a series of threats to validity. Instruments used in the assessment were validated; therefore, instrumentation threats were reduced. However, instruments were not translated into Spanish for ELL students. This may have caused some variation in accessibility of the instrument. In order to accommodate students at various levels of English language proficiency, Monica read questions out-loud to her students. The pre-post assessment design also introduced testing threats. To reduce this threat, pre-test questions were administered at the beginning of the school year, thereby increasing time between pre and post tests. Interviews with students and classroom video also provide data with respect to student learning and triangulate assessment findings.

With the acknowledgement of the iterative process of research, it is not possible to separate the researcher from his or her findings. Further threats to validity include my biases in relation to the research design, data collection, and data analysis. Some of these threats were described in the section above with respect to the role of the researcher. I further address these threats by ascribing the limitations of the claims

put forth from findings. These claims are based on the case of one particular classroom using the combined instructional approach for the first time. Thus, I do not attempt to generalize my findings beyond the scope of the classroom in which the research occurred.

### ***Data Analysis Methods***

The types of data gathered and methods of data analysis used in this study were dictated by the research-questions of this investigation. The main sources of data consisted of fieldnotes, video data, interviews and pre-post assessments. Qualitative data analysis methods were used to devise questioning and a coding scheme for the

**Table 4. Data Analysis by Data Type**

<b>Data Source</b>	<b>Description of Data Analysis</b>
Fieldnotes	Coding and memoing
Videotapes	<ul style="list-style-type: none"> <li>• Content-logging and transcription of instructional episodes addressing focus constructs; qualification of features of constructs addressed in instruction; quantification of features with respect to Tricky Tracks lesson.</li> <li>• Content analysis of student activities and conversation topics; Analysis of student engagement through non-verbal cues, or body language (on-task, hands-up, volunteering, etc.).</li> </ul>
Interviews	<ul style="list-style-type: none"> <li>• Comparison of content and student descriptions of NOS, inquiry, thoughts on instruction, and connections between science and their everyday lives in student interviews.</li> <li>• Grounded theory to draw themes from parent interviews</li> </ul>
Pre-post measure with embedded VNOS-E	Comparative analysis of content for short-answer responses
Student work samples	Content analysis for features of inquiry and NOS and bridging between school, science, and everyday understandings



purposes of systematically working through these data (Glaser & Strauss, 1967) (see Table 4). The development of the questioning and coding scheme used in this study is described below.

For the most part, different sources of data served to address different research questions; however, in some cases, the same sources of data were used for multiple purposes. For instance, certain examples and transcriptions served to inform different research sub-questions. Further, video data recordings were gathered for two purposes; that of characterizing the instructional context and understanding how students responded to classroom teaching. These same data were reviewed and processed with differing research questions in mind.

#### *Characterizing the Instructional Approach Used in the Classroom*

The first research question focused on characterizing the context of the classroom and nature of Monica's instructional approach during the Fossil Finders unit. This included observing how Monica made use of inquiry, IC, and explicit instruction in NOS, the guiding constructs of this study. Video data and fieldnotes were the primary data source to address this research question and were processed along the following schema in an iterative process:

1. Fieldnotes recorded general classroom observations and included timestamps of possible instances of inquiry, explicit instruction in NOS, and instructionally congruent practice (the guiding constructs).
2. Videotapes were content-logged and fieldnotes were used to determine tape-times for possible instances of the use of guiding constructs in the classroom.
3. Tape segments of instructional episodes possibly addressing the guiding constructs were transcribed.

4. Transcriptions of instructional episodes addressing the guiding constructs were coded using a schema focused on the features of each construct and instructional approaches.
5. Representative instructional episodes were selected to illustrate findings.

This approach to data analysis looked both across the data and in-depth, at certain contextualized moments within it. Moments of instruction grouped together across the unit make the case for the nature of the instruction that occurred in the classroom and how inquiry, IC, and explicit instruction in NOS were being brought together in this instructional setting.

Fieldnotes provided a written record of Monica's instructional implementation of the Fossil Finders study. These notes included broad observations of Monica's instructional approach along a continuum of being teacher-directed or student-centered and running notes of classroom conversations with time-stamps. Thus, fieldnotes served to reconstruct instructional days and determine moments of particular interest in each lesson. Following each instructional day, I coded fieldnotes for the possible enactment of the guiding constructs within contextualized moments of instruction, or instructional episodes. I time-stamped also these coded segments of notes for the purposes of cuing into particular sections of video to review. Fieldnotes also served as the basis for writing memos and accounts of each lesson. These fieldnotes were accompanied by video data of each instructional data.

During the study, I gathered video data on mini DV tapes each instructional day. Immediately following each lesson, I reviewed the video gathered and digitized each tape. This was a real-time procedure, during which I completed a content-log for each lesson. These content logs provide a running log of the lesson including the substance of the lesson, content-matter discussed, and actors involved. Next, I

indexed each content log for instructional episodes demonstrating the use of any of the guiding constructs in the classroom. I then cross-checked these indexed moments with fieldnotes to ascertain that all possible instructional episodes relating to the guiding constructs of this study were identified. For instance, video data that may have not captured an instructional episode may have been noted in fieldnotes and vice-versa. Further, if video data quality was poor, then fieldnotes could potentially be used to supplement the video record.

I then transcribed the instructional episodes relating to the guiding constructs of this study where data were suitable for transcription. This included episodes where speakers could be clearly heard and identified. Data were transcribed into word-for-word records of conversational turns (Sacks, Schegloff, & Jefferson, 1974), where each line of transcription indicates a new speaker. Further detail in transcriptions, such as voice inflections, were not necessary for the scope of this study. Rather, these transcriptions focus on the more critical elements of this research, such as the instructional moment and the context in which it occurred. Further, transcriptions at the level of conversational turns enabled me to gather more data with respect to who the speakers were and the frequency with which they made contributions to the class. These transcriptions served as the basis for further analysis of the classroom context and student responses to instruction.

Transcriptions, categorized by the construct they addressed, were then further analyzed along the lines of the features of each construct for a detailed content analysis of classroom instruction. To this end, I developed and used coding schema below (Table 5) based on the NSES standards for inquiry (NRC, 2000), features of the framework for IC<sup>5</sup> (Luykx & Lee, 2007), and the features of NOS (Lederman et al.,

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<sup>5</sup> It is important to note that though the framework for IC offers a numeric scoring rubric for classroom observations (Appendix E), this rubric was not used in the scope of this study. This is because the rubric was established for broad-scale studies

2004). It is important to note that though the framework for IC was developed as a number-scaled rubric for measuring the use of culturally congruent teaching in a non-bilingual classroom lesson (Luykx & Lee, 2007), it was not used for this purpose in this case study. Rather, it was used toward characterizing what sort of instruction was occurring in the classroom over the course of an instructional unit in a dual-language classroom. The numerical values associated with the rubric were not applicable in this study, as the focus of the study was directed at what features of IC were being implemented in the classroom and how they came together with inquiry and explicit instruction in NOS. Though the rubric was also originally designed to focus on non-bilingual classrooms, it could also be useful for describing the instructional context of a bilingual classroom (O. Lee, personal communication, December 11, 2008).

The questioning portions of this scheme were based on an iterative process of reviewing video and other data (Angelillo, Rogoff, & Chavajay, 2005; Jordan & Henderson, 1995). Through this process, the coding and questioning scheme was constantly drawn in comparison with actual video, fieldnotes, other observations, and further data. This coding scheme was then used to conduct content analyses of video transcriptions and interviews. To this end, the exchanges between Monica and her students were qualified along the lines of the focus constructs, or inquiry, IC, and explicit instruction in NOS, and the features of each. For example, if a conversational turn had been coded “inquiry,” I next reviewed it for the particular features of inquiry it addressed along the lines of the instructional coding scheme. Video data transcriptions were thus instrumental for establishing the classroom context and student responses to the instructional approach used. In addition, a comparative lens

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spanning multiple classrooms and was therefore not applicable to this study, which uses a case-study design.

**Table 5. Instructional Coding Scheme; Features of Inquiry, IC, and NOS**

<b>Construct</b>	<b>Features</b>	<b><i>Related coding questions</i></b>
<b>Inquiry</b>	Engage in scientifically oriented questions	<i>Are students engaging in questions?</i>
	Give priority to evidence in responding to questions	<i>Are students making use of evidence? In what ways?</i>
	Formulate explanations from evidence	<i>Are students developing explanations using evidence? In what ways?</i>
	Connect explanations to scientific knowledge	<i>Are explanations connected to scientific knowledge?</i>
	Communicate and justify findings	<i>In what ways do students communicate and justify findings?</i>
<b>Nature of Science (NOS)</b>	Tentative (subject to change)	<i>Does the teacher present science as tentative?</i>
	Empirically-based (based on and/or derived at least partially from observations of the natural world)	<i>In what ways does the teacher present science as empirically-based; related to observations?</i>
	Subjective (theory-laden, involves individual or group interpretation)	<i>In what ways does the teacher present science as subjective?</i>
	Necessarily involves human inference, imagination, and creativity (involves the invention of explanations)	<i>Does the teacher make clear that scientists make inferences, use imagination, etc? How?</i>
	Is socially and culturally embedded (influenced by the society/culture in which science is practiced)	<i>Does the teacher make clear that science is culturally embedded? In what ways does the teacher encourage students to use cultural understandings?</i>
<b>Instructional Congruency</b>	Sharing scientific authority	<i>In what ways does the teacher share scientific authority?</i>
	Use of linguistic scaffolding to enhance meaning	<i>In what ways does the teacher use linguistic scaffolding to enhance meaning?</i>
	Use of students' home languages in the classroom	<i>How does the teacher invite home /everyday languages into the classroom?</i>
	Diversity of cultural experiences and materials	<i>In what ways does the teacher introduce cultural experiences and materials into the classroom?</i>

was used to evaluate video recordings of classroom instruction over time to consider changes in Monica's instructional approach and student engagement in learning. I qualified the features of the constructs within instructional episodes in Monica's classroom, using this coding scheme. Instructional episodes, or identifiable events during the course of instruction, demonstrating the use of different features of constructs would thus illustrate Monica's instructional approach. I thus selected representative instructional episodes, based on typical moments of classroom instruction with respect to the rest of the Fossil Finders unit, to discuss in the Findings and Discussion sections.

### Tricky Tracks Analysis

I conducted an analysis of the Tricky Tracks activity of the Fossil Finders unit in Monica's classroom, to consider how the theoretical model consisting of inquiry, IC, and explicit instruction in NOS can be implemented within a classroom setting. The Tricky Tracks activity is an embedded component of the Fossil Finders curriculum that focuses on instruction in aspects of NOS. It is plausible that the constructs of inquiry, IC, and explicit instruction in NOS, may be brought together within the scope of this one instructional activity. Thus, a sub-set of video data related to the Tricky Tracks activity was drawn from across the Fossil Finders unit for a more detailed analysis. This finer-grained analysis considered which features of the three guiding constructs were evident across the lessons in which the teacher or students referred to Tricky Tracks. It also focused on identifying aspects of instructional practice that may require more emphasis to truly meet the theoretical goals of the model within the scope of this activity. This research will help inform whether, how, and to what extent an instructional approach using inquiry, IC, and explicit instruction in NOS may play out in a classroom setting.

To conduct this analysis, I narrowed my focus on instances where explicit instruction in NOS would be occurring in the classroom, how this may or may not be framed within an inquiry-based approach, and how the teacher may or may not use these instances to bring IC into science classroom teaching. To this end, content-logs and fieldnotes from the 13 instructional days of Fossil Finders activities were searched for the term “Tricky Tracks” to determine which of these days Monica or her students made reference to the activity. These instructional moments were reviewed independently, to determine how Tricky Tracks was being used in the scope of the particular lesson using the following questioning scheme:

1. Does the lesson/lesson segment reference Tricky Tracks? Y/N
2. Does the lesson/lesson segment include other examples of explicit instruction in NOS? Y/N
3. Which feature/s of NOS does the teacher/instructor refer to?
4. How does the teacher present NOS materials? (instructional approach, i.e. lecture, independent work, following what other instructional materials, etc.)

In this way, this coding scheme facilitated the process of contextualizing and qualifying the instruction enacted across the Tricky Tracks activity. This process led to identifying three of the 13 instructional days as addressing the Tricky Tracks activity directly (Day 1, Day 2, and Day 4), while three more (Day 5, Day 8, and Day 11) extending the lesson through a literacy activity. I then completed transcripts for any instructional episodes during these six days in which instruction, interaction, or group work revolved around Tricky Tracks.

These transcribed segments were coded for the instantiation of the focus constructs. I then performed finer grained coding process across the transcripts to

qualify these constructs along the lines of which features were being addressed using the questioning scheme presented above.

The following transcribed segment of Monica's instruction in her classroom (on October 6<sup>th</sup>, 2008 at tape time 58:58) illustrates how I used this questioning scheme:

Monica: That's what I wanted you to see... different perspectives, different ways that you can view the Tricky Tracks, okay? And I want you to think back, do you remember... a [recent] question [we had] that said: "if scientists all have the same facts, how come they have different theories on what may have happened to dinosaurs?"... [long pause]  
If they all have the same facts, why do they have different theories, remember we said it was different stories? This is the perfect example of how we can have the Tricky Tracks, the same facts, the same observation, but yet we are making different inferences, right? Different takes on what could have been. Does that make sense to you?

In response to the first question, Monica includes explicit instruction in NOS in this segment. The features of NOS she addresses here include that scientific knowledge is: (a) empirically-based, (b) subjective, and (c) necessarily involves human inference, imagination, and creativity. For example, in this segment she refers to observations and facts. Moreover, she explains how using the same information, students in the classroom have been coming up with different inferences, or "different takes on what could have been." Monica however, does not address science as being tentative or the social/cultural influences on scientific knowledge in this segment.

### *Understanding Student Experiences*

This study focuses on gathering evidence with respect to understanding students' experiences in the context of a classroom using an inquiry-based



instructional approach combined with IC and explicit instruction in NOS. The research sub-questions driving this aspect of the study focused on: (a) learning about how students engaged in inquiry; (b) how they bridged science learning with their everyday understandings; (c) what their views about NOS were and how they shifted as a result of instruction; and (d) what kind of learning occurred in the context of the classroom. Data gathered to address these research sub-questions included video data of classroom instruction, interviews, pre-post assessments, and student work samples (Table 3). Each of these data sources required a different method of data analysis, though in some cases, multiple data sources were used toward addressing a particular research question. For example, video data, pre-post assessments, and student work samples were all used to understand student learning. The data analysis methods presented below are organized with respect to the research sub-questions they address.

#### In what ways do students engage in scientific inquiry?

Video data and fieldnotes served as primary data sources to understand how students engaged in scientific inquiry. These data were processed using the same coding scheme (Table 5) and methods described above, with respect to analyzing the instructional approach used in the classroom. Data analysis using the coding scheme revealed instructional moments in which inquiry was being implemented.

Transcriptions of these sections indicated whether or not Monica's students were engaged in inquiry during the instructional episode. Video data transcriptions were thus instrumental for gathering an understanding of student responses to the curriculum in this setting. Instances of student involvement inquiry followed the coding scheme to determine: (a) what content-matter students were engaged in, (b) what features of inquiry students were involved in, and (c) what student behavior characterized this involvement. In essence, data analysis with respect to students' use

of inquiry included a content analysis, analysis of the features of inquiry, and behavioral observations. The content-analysis component included noting what students were engaged, in talking, about or doing. For example, student conversations were categorized with respect to considering the shapes of fossils or where fossils may come from. These data revealed emergent themes with respect to how students may connect everyday understandings to science, as described in the Results section. Aspects of inquiry that students were involved in were determined using the coding scheme with questions based on the features of inquiry included in the NSES (NRC, 2000). These instances of involvement in inquiry were thus based on student activities in the context of their classroom. Evaluating student engagement in learning was grounded in observations of the verbal and non-verbal cues during class time and in videos of classroom instruction. Verbal cues included whether conversation topics were on-task and whether students were volunteering to give answers, share their findings, etc. Non-verbal cues included whether students were alert and seemed interested in learning, as opposed to having their heads down on their desks and seemingly withdrawn. Raising hands, actively observing fossils, and on-task collaboration were also cues of student engagement in learning. Together, these data serve to inform whether and how students engaged in inquiry within the context of classroom instruction.

#### How do students bridge their everyday knowledge and science?

Video data and fieldnotes also address research questions focused on how students may bridge everyday knowledge and science. Content analyses of classroom video data and fieldnotes were conducted in search of comparative examples and analogies. Examples of this would be students likening a fossil to another object or using an example of an everyday understanding to explain science, whether during

formal instruction or in an informal conversation with peers or their teacher. Interviews with focus students also served as a data source to address this question. As in the case of video data and fieldnotes, student interviews were reviewed for content-matter comparisons. As described above, student interview questions followed a protocol (Appendix H). Comparative questions were included in the interview, where students were asked to describe how they do science at home and how they do science at school. Interviews were also conducted with focus students' parents following another interview protocol (Appendix J). In these interviews, parents were also asked their views about the use of science in home and other settings. Student work samples also served to address this research question. I reviewed focus student notebooks and projects for the use of everyday life examples. Together, these three data sources triangulated findings about how students connect science to their everyday lives.

What are students' views about scientific inquiry and NOS, and how do these change during the investigation?

Interviews and the VNOS-E assessment measure served as the primary data sources to address this research question. As described above, interviews were conducted with the five focus students. A content-analysis of running notes associated with these interviews was conducted using the features of inquiry (NRC, 2000) and NOS (Lederman et al., 2004) as guidelines. Initial student responses to interview questions were then compared to responses on the follow-up interview. Further VNOS-E assessment questions were embedded into the pre-post tests taken by Monica's students. A content-analysis of focus students' pre- and post- test responses was conducted using the features of inquiry and NOS as guidelines. Student responses on the pre-test were then compared to responses to the same question on the post-test

and again to responses on the retention test, which was implemented several months later.

#### How are students supported in content-area learning?

The pre-post assessment implemented in this study contained multiple-choice questions focused on geological content-matter. Student responses on the pre-test were compared to student responses on the post-test. Descriptive statistics were used to calculate overall change in classroom responses to determine student learning. Because of testing effects and language barriers for certain students, video data served to triangulate the pre-post measure. Video data captured student conversations about geological content-matter across the instructional unit. A comparative content-analysis of transcripts across the unit was conducted. This analysis focused on how students made reference to geological content-matter at different points in time in the unit.

#### Emergent Findings

Data collection in the field and video data review also contribute to emergent findings. Emergent findings consisted of patterns noticed during the coding and memoing of notes and transcriptions. These patterns presented new considerations beyond the scope of the original research questions, which were further explored across data.

## CHAPTER 4

### RESULTS

The main goal of this research was to better understand how underrepresented students may be supported in science learning through a combined IC, inquiry-based instructional approach, coupled with explicit instruction in NOS. This study explored how this form of instruction may be implemented in the context of an authentic research investigation and how it, in turn may support underrepresented students' understandings of science. The following chapter presents results and findings related to the implementation of the inquiry-based Fossil Finders curriculum in an urban dual-language 5<sup>th</sup> grade classroom. First, an overview of the classroom implementation of the curriculum will be presented. The next part will present findings related to the research question: *How did the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach?* Following this section, I will present research findings related to the question: *How did underrepresented students experience and respond to an instructional approach combining inquiry, instructional congruency and explicit instruction in NOS?* Next, I will present two sections of emergent findings beyond the scope of the original research questions. These sections include addressing findings related to combining the classroom context and student experiences and findings related to students' everyday and cultural experiences.

#### ***Overview of Classroom Implementation of Curriculum***

The focus teacher, Monica, implemented the Fossil Finders curriculum over 13 instructional days between the months of September and December in 2008. Monica

enacted the curriculum in block periods of time spanning between 30 and 90 minutes on the Mondays, Tuesdays, or Wednesdays of each week. She began the unit with the Fossil Finders background lessons about NOS and fossil identification (Appendix M). These lessons were designed to prepare students for the actual Fossil Finders investigation. Table 6 below presents a timeline for the instructional unit implemented in Monica's classroom.

During instructional Days 1 and 2, Monica initiated the Fossil Finders curriculum Tricky Tracks background lesson. As described above, this lesson was modified from the NAS (1998) "Proposing Explanations for Fossil Footprints" activity and formed an integral component of the Fossil Finders curricular approach. The purpose of this lesson was to introduce students to aspects of NOS and in particular, to learn to differentiate between making inferences and observations. Though this lesson does not engage students with authentic data, it models the activities of scientists and how scientific knowledge is tentative and may change based on the availability of new information. Thus, students have an opportunity to learn about the empirical nature of scientific work through the context of this activity.

During Day 3, Monica introduced the actual fossil samples to the Fossil Finders Leaders, a group of 8 students with higher levels of ELP. Because of their higher levels of ELP, the Fossil Finder leaders remained in class while the rest of the students received specialized language instruction outside the classroom, working in small groups in the hallway. These Fossil Finders Leaders, were given a collection of fossils that Monica gathered over the summer. These fossils were not the unknown fossil samples related to the Fossil Finders investigation, but rather a set of fossils hand picked by the teacher for use in helping students practice identifying different

**Table 6. Fossil Finders Curriculum Implementation Timeline**

<b>Day 1</b>	<b>Day 2</b>	<b>Day 3</b>	<b>Day 4</b>
9/30	10/6	10/7	11/17
Tricky Tracks	Dinosaur Stories; backwards Tricky Tracks	Vocabulary;  Fossil Exploration	Tricky Tracks Stories
<b>Day 5</b>	<b>Day 6</b>	<b>Day 7</b>	<b>Day 8</b>
11/24	12/1	12/2	12/3
Fossil Identification	Fossil Finders Leaders Fossil Measurements Class Fossil Measurements	Fossil Finders Leaders Data Sheets "Fossil Fever" Read Aloud Tricky Tracks Stories	Tricky Tracks Stories
<b>Day 9</b>	<b>Day 10</b>	<b>Day 11</b>	
12/8	12/9	12/10	
Ask a scientist prep	Ask A Scientist: PRI visit	Fossil Finders Investigation Continued	
Fossil Finders Website	Fossil Finders Investigation		
<b>Day 12</b>	<b>Day 13</b>	<b>Other</b>	
12/12	12/15	<i>Monica Enter Data</i>	
Verifying Data	Data Review	<i>Rocks Tell Stories</i>	

types of fossils. Monica asked students to observe the fossils and make inferences, and draw conclusions, about what organisms were fossilized without providing any greater details. As students looked at these fossils they made inferences, that they were seeing bones, fingers, fish, and so on. Monica allowed the students to retain their initial inferences without correcting them. As the other students returned to class from their specialized language instruction, they were placed into four collaborative groups and expected to join the ongoing classroom activities. Each of these collaborative groups included two of the Fossil Finders leaders. These leaders shared instructions about the activity they were involved in while the others were gone. As students

worked in their groups, Monica made her way across the classroom and interacted with each group. In this way, Monica was able to provide students with a collaborative learning space and address the learning needs of students at various levels of ELP.

During Day 4, Monica reintroduced the Tricky Tracks activity, and added a story-writing component. She revisited the concept that scientists form different interpretations from the same data. She then invited students to write stories about their own interpretations of what may have occurred in the Tricky Tracks scenario. Monica then provided scaffolding related to writing stories, such as providing a title and setting, through the use of graphic organizers. In this way, Monica was able to integrate her school district's requirements for instruction in English language arts into science instruction and also practice features of IC.

During Day 5 of instruction, Monica provided students with a key to begin identifying the practice fossils. Students began to learn the names of different fossilized organisms and how to differentiate between them, based on their sizes and shapes. Students also practiced measuring these fossils and filling out data sheets related to the type of fossil they were observing, its size, color, and condition. Throughout the next few days of instruction, Monica repeatedly asked students to make inferences about the environment in which these organisms had once lived. Students also continued to work on their Tricky Tracks stories during this time and focused on providing background information on the setting, or details about the environment in which the tracks were set, for their stories. Monica continued to synthesize the conversations related to the Tricky Tracks writing activity and making inferences about the environment in which the fossilized organisms once lived. Through this scaffolding, students began to infer that their local environment had once been covered by a tropical ocean.



Day 6 of instruction occurred on the Monday following Thanksgiving break. During this lesson, Monica provided Fossil Finders Leaders with instruction on how to measure length and width of fossils. Monica also referenced a prior lesson on how to convert from centimeters to millimeters to help students connect what they had previously learned to what they would need to do as a part of the investigation. The Fossil Finders Leaders practiced measuring fossils. Later they explained what they had been doing to group members who had attended specialized language instruction. Monica also provided students with datasheets to practice recording their fossil measurements. Analysis of student work on these data sheets revealed that students were having difficulties with metric conversions. Consequently, Monica provided additional instruction on making metric conversions.

On Day 7 of instruction, students continued to practice measuring fossils and familiarizing themselves with the data recording sheets. However, some students still demonstrated having challenges with metric conversions and fossil identifications. The second part of class was dedicated to a read-aloud activity from a children's fiction book called "Fossil Fever." As Monica read to her students, she asked them to use evidence to make predictions about what would happen next in the storyline. In this way, Monica was again integrating literacy activities with science. Monica used this book to initiate conversations about where fossils can be found and environmental changes over time. She then showed students an image of a tropical sea with the living organisms that are now fossilized. In response, students drew on examples of their knowledge about fossils and tropical climates. Students then returned to further working on their Tricky Tracks stories.

Day 8 of instruction consisted of Monica working on the Tricky Tracks stories with the Fossil Finders leaders. These students later presented their draft stories to the rest of the classroom for comments and feedback. Monica commented on how the

student stories needed to connect to the tracks seen in the poster, as some students created fictitious accounts beyond the scope of the evidence they had. Students continued to work on their stories at their desks, while Monica met with individual students to discuss and comment on the progress of their stories.

After having interacted with actual fossil samples, students began to prepare for a geologist's visit to their classroom. On Day 9, students drafted questions they would ask the scientist in their journals. They also visited the Fossil Finders website and entered their questions into the "Ask a Scientist" component of the site. Students asked the visiting geologist, Trina, these same questions the following day. Trina established a friendly rapport with students through her enthusiasm about fossils, storytelling, and joking about being a "geeky" scientist. At the same time, she held students accountable for what she had already discussed with them. For example, when a student who returned to class from specialized language instruction repeated a question that had already been asked, Trina asked the first group of students to address his question.

Monica initiated the Fossil Finders Investigation, the central component of the inquiry-based investigation of the Fossil Finders project, on Day 10. Students worked in small groups to identify, measure, and record data related to the fossils that were shipped from shale deposits in upstate New York, as discussed above. For the most part students were mostly able to correctly identify the type of fossil they were seeing and the differences between brachiopods and clams. Thus, they demonstrated learning science concepts since Day 3 of the curriculum unit, where they had identified fossils of the Devonian period as bones, fingers, and fish. Students also engaged in lively arguments about what they were observing and the processes of working through data. Students, for example, asked questions about whether they should measure a sample and then set it aside, and what would happen if they measured the same fossil twice.

Student groups continued working to identify, measure, and record information related to fossils in the sample sets through Day 11 of the unit.

On Days 12 and 13, students worked on completing the Tricky Tracks stories independently at their desks. During this time, Monica met with individual student groups in the back of the classroom to review the samples they had recorded on their data sheets. Each group verified the information recorded on their data sheets, such as the type of fossil and its measurements. At times, Monica found errors in measurements. However, at other times students argued the reasons for why their data was correct. Due to time constraints, Monica did not have students enter their data into the online database and the verification work concluded her students' involvement in the Fossil Finders investigation. Though working with the database was an important component of the Fossil Finders curriculum, Monica entered student data in the database herself at a later time. As a result, students only experienced certain aspects of the inquiry related to fossil identification and measurement.

Further aspects of the investigation available to teachers included the compilation of aggregate data and an analysis of classroom data in relation to the data gathered by other classes at other geological horizons. Data gathered at different horizons demonstrate evidence of the kinds of sea life found at different points in time. A comparison between horizons using evidence would have allowed for students to make inferences about changes in sea life over time. Nonetheless, findings below indicate student understandings of these concepts, even though they did not complete the entire investigation.

Later in the school year, Monica provided students with other instruction related to rocks and fossils. Students learned about the rock cycle and where fossils fit into this cycle. Student work samples illustrated students drawing from their knowledge-base about fossils based on the Fossil Finders unit during this time. How

Monica implemented this instructional approach with respect to the focus constructs of this study is presented in the next section.

***The teacher's implementation of inquiry, IC, and explicit instruction in NOS***

This section presents findings related to how Monica implemented an instructional approach using the guiding constructs of this research in the context of the Fossil Finders curriculum. Classroom observations consisting of fieldnotes and videotapes comprised the primary sources of data collection to this end.

Characterizing the instruction in the classroom consisted of gathering fieldnotes focused the roles of the teacher and her students. Additionally, videotaping was used throughout the unit to capture Monica's use of inquiry, IC, and explicit instruction in NOS. An analysis of classroom video from lessons across the instructional unit identified where Monica made use of the focus constructs in her teaching and categorized each instance by its respective features.

Excerpts of transcripts from instructional episodes representative of Monica's teaching approach during the unit are included below. These episodes were representative of the other instructional exchanges in Monica's classroom. An additional analysis of the Tricky Tracks activity was conducted to determine how these features came together in instruction. Table 7 summarizes findings from the data analysis:

**Table 7. Classroom Context Data Analysis Using the Three Guiding Constructs**

	<b>Construct</b>	<b>Observations and Findings</b>
1	Inquiry	There was evidence that the nature of the classroom environment shifted from teacher-centered questioning to student-driven questioning and inquiry over the course of the instruction; within this context, Monica addressed all essential features of inquiry with particular attention to the use of evidence in scientific research.
2	IC in the classroom	Monica demonstrated regular use of IC strategies in teaching science, which included extending regular science learning activities into literacy-focused assignments.
3	Explicit instruction in NOS	During instruction Monica provided explicit instruction related to certain features of NOS; however, she did not address all features of NOS or consistently connect classroom activities to the authentic work of scientists.
4	Constructs Combined	Though Monica implemented features of inquiry, explicit instruction in NOS, and IC, not all features of each construct were implemented as designed in the Fossil Finders curriculum.

Evidence for the teacher's use of these constructs is grounded in video data. I selected video segments that had 1) high video and audio quality and 2) addressed a research sub-question or provided evidence to support another emergent finding. These video transcriptions provide a record to qualify the instructional approaches used by Monica from the beginning to end of the Fossil Finders curriculum. Exchanges between Monica and her students were categorized along the lines of the focus constructs, or inquiry, IC, and explicit instruction in NOS, followed by a secondary qualification addressing the particular feature of that construct (see Table 5). For example, if Monica made a statement or enacted an instructional approach that would correspond with explicit instruction in NOS, this exchange was categorized by its corresponding feature, such as the tentativeness of science. Video data transcriptions were instrumental for characterizing the instructional approach used during the Fossil Finders unit. Supporting evidence for how Monica enacted the focus constructs and their features is presented in the next four sections: 1) the implementation of inquiry, 2) instructional congruency in the classroom, 3) explicit

instruction in NOS, and 4) a combined instructional approach between these three constructs.

### *Implementation of Inquiry*

Inquiry entails both an instructional approach that stems from constructivist thinking and particular features that liken it to the practices of science. The implementation of inquiry is thus dependant on the instructional approach used by teachers. For example, a student-centered (SC) instructional approach, where students actively engage in building knowledge embraces inquiry, as opposed to a teacher-directed (TD) instructional approach, where educators convey knowledge to students through didactic teaching (NRC, 2000). Consequently, it is important to consider both the nature of Monica's teaching in relation to constructivist notions and which of the five features of inquiry her teaching addressed at particular times. Video data provide evidence of Monica implementing various features of inquiry across a continuum of a TD to SC teaching during the Fossil Finders instructional unit. Portions of this unit illustrate the amount of TD instruction as compared to SC learning in Monica's classroom. These data demonstrate how Monica's instructional approach evolved as the Fossil Finders unit was implemented.

Taken together, episodes from lessons across the Fossil Finders unit demonstrate that Monica addressed the five essential features of inquiry to different degrees over the course of instruction. These features require that students: (a) engage in scientifically oriented questions, (b) give priority to evidence in responding to questions, (c) formulate explanations from evidence, (d) connect explanations to scientific knowledge, and (e) communicate and justify findings (NRC, 2000). Together, these features form the foundation for introducing scientific activity and culture to the classroom. Data indicate to what extent Monica addressed these features

as well as the variation in Monica's instructional approach to implementing inquiry (p. 29).

Monica's implementation of inquiry across the Fossil Finders instructional unit is illustrated in Table 8 below. The purpose of this table is to consider whether and how features of inquiry were addressed in Monica's classroom across the instructional unit. Thus, this table summarizes the key features of inquiry Monica addressed during each instructional day that were captured by video and fieldnotes. An understanding of Monica's instructional approach, with respect to inquiry and the other focus constructs of this study is fundamental to drawing inferences about the science learning experiences of students in her classroom. Other tables presented in this chapter address NOS and IC, the other focus constructs of this study.

Students in Monica's classroom did not complete the authentic scientific investigation in its entirety. However, they were able to experience the five features of inquiry, to some extent, throughout the portions of the Fossil Finders unit Monica carried out. Further, there was variation in the extent to which inquiry was framed by TD or SC instruction. For example, though students did not engage in pursuing their own research questions, as in the case of open-inquiry, Monica provided them with questions to pursue and opportunities to grapple with data. Further, when students were introduced to fossils for the first time on Day 2, Monica asked students to determine whether the organisms were plants or animals and what their habitat may have looked like. Students had no previous instruction related to these fossilized organisms, and inquiry in this instance may be characterized as TD inquiry. As students became more familiar with the actual fossil samples and learned to identify what they were seeing, Monica introduced them to the guiding question of the Fossil Finders curriculum: *Do the animals in the shallow Devonian sea stay the same during environmental changes?*

**Table 8. Features of Inquiry across the Fossil Finders Instructional Unit**

<b>Instructional Day</b>	<b>Instructional Approach and Nature of the Event</b>	<b>Features of Inquiry and Description of How Used</b>
<b>Day 1</b> 9/30/2008	Teacher-Directed (TD); Monica mainly used a teacher-directed instructional approach and employed an initiation-response-evaluation (IRE) approach to questioning	Instruction focused on students' use of evidence to formulate explanations (EE). For example, when talking about fossil tracks, the tracks did not "go home" because there was no evidence of the animal turning around.
<b>Day 2</b> 10/6/2008	Student-Centered (SC); Monica mainly used a SC instructional approach to introduce fossils; Transitioned to a TD teacher-directed instructional approach to connect learning to prior instruction and knowledge about prehistoric animals	Instruction focused on students addressing a scientifically oriented question (SQ) and observing data samples to gather evidence to respond to questions (EQ). For example, Monica engaged students in observing fossils to address the broad question "what are they?;" students were then involved in connecting their explanations to scientific knowledge (SK)
<b>Day 3</b> 10/7/2008	Monica mainly used an SC instructional approach; Students worked in groups to observe fossil samples and determine what they were seeing.	Students engaged in addressing question (SQ) related to what kind of organisms they were observing and what kind of environment they must have lived in; instruction focused on students observing data samples to gather evidence (EQ); for example, students engaged in open-ended observations of fossils and note-taking; students then formulated explanations (EE); for example, students explained what fossils they thought they were seeing based of evidence from the rocks.
<b>Day 4</b> 11/17/2008	Monica used a mixed TD/SC instructional approach; Monica revisited the Tricky Tracks activity and provided scaffolded guidance for a writing activity; Students worked independently on their stories.	Instruction focused on reiterating the important of basing explanations on evidence (EE). For example, Monica reminded students that Tricky Tracks stories must somehow incorporate the footprints.



**Table 8 (Continued)**

<b>Day 5</b> 11/24/2008	Monica mainly used a SC instructional approach; students worked in groups to observe and identify fossil samples.	Instruction focused on students giving priority to evidence in responding to questions (EQ) and formulating explanations using evidence (EE). For example, students identified the fossils samples they were observing and provided rationale for how they identified their fossil samples.
<b>Day 6</b> 12/1/2008	Monica mainly used a SC instructional approach; students worked in groups to observe, identify, and measure fossil samples; Monica built on prior learning about the metric system to prepare students for measuring fossil samples.	Instruction focused on students giving priority to gathering evidence in responding to questions (EQ) by reviewing fossil samples to gather measurements of fossils, or data to be used as evidence.
<b>Day 7</b> 12/2/2008	Monica used a hybrid SC/TD instructional approach; students first observed data samples to gather measurements of fossils, or evidence; Monica transitioned to a story-telling instructional approach with a read-aloud activity about fossils and the environment in which fossilized organisms students were observing had lived in.	Instruction continued to focus on students giving priority to gathering evidence in responding to questions (EQ) by reviewing fossil samples to gather measurements of fossils, or data to be used as evidence; Students posed and explained predictions for what would happen next in the story using evidence (EE). Students connected their explanations to scientific knowledge (SK) and communicated and justified their reasoning (CE).
<b>Day 8</b> 12/3/2008	Monica employed a SC and mostly “hands-off” instructional approach; Students worked individually on writing stories	Students conducted independent work and engaged in writing their Tricky Tracks stories
<b>Day 9</b> 12/8/2008	Monica employed a SC and mostly “hands-off” instructional approach	Students conducted independent work; they browsed the Fossil Finders website and prepared questions to ask the visiting scientist

**Table 8 (Continued)**

<b>Day 10</b> 12/9/2008	Monica mainly used a SC approach to instruction and informal conversation with students during the scientist's classroom visit; students asked the visiting scientist questions they had prepared the day before; Monica mainly used a hybrid TD/SC and guided-inquiry to implement the Fossil Finders investigation	Instruction focused on implementing the Fossil Finders investigation using the actual fossil samples; students engaged in an exploration of actual fossil samples to gather data (SQ; EQ; EE)
<b>Day 11</b> 12/10/2008	Monica continued to use a hybrid TD/SC approach and guided-inquiry to reintroduce and implement the Fossil Finders investigation	Instruction focused on implementing the Fossil Finders investigation using the actual fossil samples; Students engaged in an exploration of actual fossil samples to gather data (SQ; EQ; EE)
<b>Day 12</b> 12/12/2008	Monica mainly used a TD approach to verify the data and measurements a student group gathered	Instruction focused on confirming the fossils a student group identified and reviewing the group's fossil measurements; Students justified their data using the fossil samples (CE).
<b>Day 13</b> 12/15/2008	Monica mainly used a TD approach to verify the data and measurements a student group gathered	Instruction focused on confirming the fossils a student group identified and reviewing the group's fossil measurements; Students justified their data using the fossil samples (CE).

At this point, Monica assumed more of a facilitating role in instruction. Students worked in small groups to observe fossil samples and Monica moved around the room to comment on what students were seeing and to address student questions. Her instructional approach notably shifted from the teacher-directed instructional approach used on Day 1 to a student-centered approach characterized by the informal conversations she held with students. Monica adopted a hybrid instructional approach

during the final days of the curriculum unit, where she used a teacher-directed approach to verify student data and measurements for accuracy but based on reports from students based on their findings. In this case, Monica again adopted more of an authoritative position, but also provided opportunities for students to defend their data and challenge her.

Along these lines, a change in Monica's questioning patterns illustrates a shift in her instructional approach. While Monica initially elicited teacher-directed questioning, she gradually transferred her instructional approach to one that invited student-centered questioning. Within this space, students also pursued answers to their own questions. Evidence to show changes in the nature of the classroom questioning is presented below and supports the following finding: *Throughout the Fossil Finders instructional period, the classroom community shifted from primarily teacher-directed questioning to a classroom environment exhibiting student-driven questioning and inquiry.*

First, video transcriptions provided data for categorizing the types of interaction between Monica and her students. Complete transcriptions of instructional episodes provided evidence of the main speaker at a particular moment in time, the amount of time each participant takes the verbal stage, the types of questions asked by the teacher and the students, and how the teacher responds to student questions. Video data also provided records of how these interactional moments may shift to correspond with the instructional approach used by the teacher. For example, when Monica used a teacher-directed instructional approach, student questions were limited and Monica employed an initiation-response-evaluation approach to questioning. Nonetheless, at times she adapted more of an initiation-response approach, without an evaluative component. This may provide evidence for a shift towards using more of an inquiry-based approach. Further, when instruction was student-centered and inquiry-oriented,

students began to ask “I wonder...” and other connection-making questions, rather than clarifying questions. An example of the differences in questioning and responses can be seen across the following exchanges, which are representative of other conversational exchanges on the same dates:

Scenario 1: (Day 1, September 30, 2008; Lines 90-94)

- Monica: What makes us think that there’s only two animals involved?...  
What makes us think that? [Matias raising hand] Matias?
- Matias: Because there’s only two pairs of footprints.
- Monica: Only two pairs of footprints! And, we know from our own past experiences, if you’ve ever walked in the snow that hasn’t been touched? So, you only see one set of footprints. Right? So, we know from past experiences that it’s possibly just one animal because there’s not a bunch of footprints together. Right? Is that how you’re making that inference?
- Students: Mmmm...hmmm...
- Matias: Yes

Scenario 2: (Day 2, October 6, 2008; Lines 31-34)

- Raul: Miss, are these like ordinary seashells?
- Monica: What happened?
- Raul: [repeats question] are these like ordinary seashells?
- Monica: I'm not going to give you the answers, Raul. I want you to use your imagination to make an inference about what you think you might see.

In the first scenario, Monica used a teacher-directed approach to ask the class questions related to the Tricky Tracks instructional activity. Yet, she also modeled the use of evidence in constructing explanations, an essential feature of inquiry. This tension between teacher-directed and student-centered questioning manifested itself in other ways as well. For example, though this instructional episode is inquiry-oriented and students are invited to make observations and inferences about what they see,

Monica took on the role of expert, either affirmed or disaffirmed a particular student response. She thereby rebounded to more of a teacher-directed instructional approach and took on the stance of classroom (and scientific) authority. In the second scenario, students sorted through a bag of unknown fossils and made observations. Rather than Monica directing questions to the students, the students asked questions of their teacher. As evidenced in the transcription excerpt in the second scenario, Monica declined to answer Raul's question. She used the rationale that he needed to think for himself. Her response encouraged greater student authority in resolving questions; however, was framed *as if* there is a correct answer that she withheld from her students. These exchanges are representative of the general forms of interaction between the teacher and her students throughout the instructional unit. This gradual shift is characterized by further interactions, where the teacher eventually, completely shifted the authority to her students. For example, she deferred to her students as to the pronunciation of "pteronodon" and later agreed with students' fossil identifications based on the justification they provided.

Though these lessons differed in their purpose and are illustrative of the differences between an introductory lesson and a lesson later in the unit, they nonetheless illustrate the tension between Monica's attempt to implement an inquiry-based approach and maintain classroom authority from an evaluative stance. Moreover, these data support the claim that throughout the Fossil Finders instructional period, the classroom community shifted from teacher-directed questioning to a classroom environment exhibiting student-driven questioning as a part of inquiry. For example, though the teacher initially exhibited the use of student-centered questions, she maintained traditional initiation-response-evaluation questioning patterns, which are characteristic of teacher-directed instruction. Over time, her guided approach to inquiry gradually opened to allow for a greater student questioning and a more

student-driven approach. These observations are triangulated by Monica's reflections related to her instructional approach, where she commented "I think sometimes, after you've been in education for so long, that you forget that you do not want to just point out and say 'this is a trilobite.' Instead, we want to say, 'what does this look like to you?'" (October 7, 2008, Tape MV3, Time 36:00). In this statement, Monica demonstrated being cognizant about wanting to use a more student-centered questioning approach in inquiry.

Monica also addressed the essential features of inquiry within this instructional context. While some of these instances of instruction were framed by a teacher-directed approach, others were framed by a student-centered approach. For example, Monica used a teacher-directed approach to model making use of evidence to justify explanations and tying explanations to scientific knowledge, both features of inquiry. Transcriptions provide evidence of Monica emphasizing these features of inquiry. This can be seen in the following transcription on Day 1 of instruction (September 30<sup>th</sup>, 2008; Line 203):

Monica: I like the way that everyone is saying that one dinosaur went home because we don't like to think that one dinosaur ate the other dinosaur. You don't like to have that happen. But, actually that's the food-chain. It does happen for survival. One animal, we knew that one footprint is smaller than the other. And we saw the larger one. So, we knew that one... the larger animal most likely is going to be able to eat the smaller animal and defeat it. And that he will be the predator and he's going to eat it, right? And that's how he's going to survive, right? So, we like to say he went back home, but if you look at the footprints, we didn't see the footprint going back home. Okay? So we really can't infer that a footprint went back home, though it's a nice thought, we don't like to think that one animal ate the other, but we know that that happens in nature. One animal eats the other, we know that?

Here, she addressed the anthropomorphic explanations that students gave for what had occurred across the Tricky Tracks scenario and the need to use evidence when constructing explanations (a feature of inquiry). In her statement, “We don’t like to think that one dinosaur ate the other dinosaur...but, actually that’s the food-chain,” Monica gives an example of connecting explanations to age-level appropriate scientific knowledge (NRC, 2000, p. 27). Moreover, she demonstrates the need to use evidence in constructing explanations with her comment on the direction of the footprints. “If you look at the footprints, we didn’t see the footprint going back home.” These comments were reiterated later during instruction.

Students communicated their understandings and data-based interpretations through oral presentations to the rest of the class members. These presentations consisted of a volunteer student (oftentimes ones with higher levels of ELP as further described below) standing in front of the class and reading his or her work aloud to the rest of the classroom. Though student presentations were a regular part of classroom instruction prior to the Fossil Finders unit, Monica modified these student presentations to embrace features of inquiry, such as the communication and justification of findings. Further, both Monica and students’ peers in the class provided feedback to the presenting student, focused on good use of vocabulary, scientific knowledge, descriptions, etc. Monica thus used this time to comment on the importance of the use of evidence when formulating explanations. For example, when Isabel and Bianca shared their stories about dinosaurs without making reference to the evidence, Monica commented:

Monica: What I have a comment about for both of you and for anybody else is that the Tricky Tracks was a great story starter for you, but we’re not connecting back to our Tricky Tracks. So, for Isabel, I would want you to add in there: How did the Tricky Tracks lead you to the escaped T-Rex. And, I want you, Bianca, to tell me how did the

Tricky Tracks lead you to the dinosaur egg. Okay? So we have to incorporate the Tricky Tracks in our stories. If you don't have that in there, I will come up with a question for you and then you'll be able to incorporate. Okay?... (Day 8, December 3<sup>rd</sup>, 2008; Line 24).

Here, Monica again referred to the need to use evidence in constructing explanations. In this passage, she also indicated she would be providing students with instructional scaffolding to meet this goal by formulating guiding questions for these students. Together, these passages indicate Monica's attempt to implement an inquiry-based instructional approach in her classroom and to facilitate student engagement in the various features of inquiry.

Monica demonstrated beginning to use some of the features of inquiry regularly, though her instructional approach shifts from one of teacher-directed to student-centered instruction and back. At times, her instructional approach became a hybrid of the two, based on the activities she involved her students in. Interestingly, Monica used a direct-instruction approach to point out elements of inquiry to her students, such as understanding the use of observations. These findings mostly fall in line with the anticipated outcomes of the use of inquiry in a classroom setting. For example, it is not likely for a teacher to utilize inquiry during all phases of instruction; rather the use of inquiry is dependent on lesson objectives. For instance, during the introductory phases of a lesson or unit, it is possible for a teacher to use a teacher-directed approach to provide background information, and during this time students are not engaged in scientific activities.

These findings also demonstrate that Monica did in fact address all of the features of inquiry through classroom instruction over the course of the Fossil Finders unit. However, she did so in to varied degrees. For instance, students did not demonstrate pursuing research related to their own questions. Further, though the instructional unit included an inquiry-based investigation, students did not complete



all of its components. They nonetheless demonstrated addressing the various features of inquiry, such as making use of evidence to construct explanations; or using the fossil itself to determine, explain, and defend the type of fossil they were observing. The key point here is that evidence indicates that students were provided with learning opportunities to engage in all of the features of inquiry over the course of the Fossil Finders instructional unit.

### *Instructional Congruency in the Classroom*

Video data and fieldnotes provide evidence of Monica implementing the various features of IC over the course of the Fossil Finders instructional unit. Given the dual-language classroom context, many features of IC, such as the use of home languages in the classroom and linguistic scaffolding to enhance meaning were already an integral part of classroom instruction. However, Monica also demonstrated bridging between students' cultural and everyday ways of knowing and science, as well as a sharing scientific authority with her students to different degrees across the instructional unit. Establishing the regular use of IC in the classroom is critical to further considering how this instructional approach can be combined with inquiry and explicit instruction in NOS.

Data indicate that Monica fairly regularly implemented features of IC in her classroom (see Table 9). Many of these practices were already established in the classroom prior to the Fossil Finders unit. For example, Monica did not have to teach students about using graphic organizers as a part of Fossil Finders instruction. Rather, she relied on previous instruction and made use of prior student knowledge to adopt the graphic organizer for writing the Tricky Tracks stories. Moreover, Monica did not need to clarify that students could use their native and everyday languages in the classroom. This was already an established classroom norm. The following evidence

**Table 9. Instructional Congruency across the Fossil Finders Instructional Unit**

<b>Instructional Day</b>	<b>Features of Instructional Congruency evident in the lesson</b>	<b>Description of the use of instructional congruency in the lesson</b>
<b>Day 1</b> 9/30/2008	Shared scientific authority (SA) with students; Invited the use of home language (HL) into the classroom; Made use of students' cultural and everyday experiences as a part of instruction (CE)	Monica allowed students to interpret the Tricky Tracks scenario in their own ways; Provided additional instruction and clarification to certain students in Spanish; Connected student understandings of "snow" and leaving behind "footprints"
<b>Day 2</b> 10/6/2008	Mostly shared scientific authority with students (SA); Used linguistic scaffolding to enhance meaning (LS); invited the use of home language into the classroom (HL)	Monica provided students with fossils and a task to make inferences about the organisms they were seeing; used books to share illustrations about dinosaurs; provided additional instruction and clarification to certain students in Spanish;
<b>Day 3</b> 10/7/2008	Makes use of linguistic scaffolding to enhance meaning (LS); students make use of home language in the classroom (HL)	Monica used curriculum KWL vocabulary charts; students used Spanish when working in groups; students informally used Spanish when talking to Monica
<b>Day 4</b> 11/17/2008	Mostly shared scientific authority with students and framed students as potential scientists (SA); made use of linguistic scaffolding to support students in story-writing (LS)	Monica provided students with opportunities to interpret fossil tracks in the Tricky Tracks scenario in their own way with multiple plausible explanations; Monica introduced graphic organizers to the story-writing process
<b>Day 5</b> 11/24/2008	Mainly used a student-centered instructional approach to share scientific authority (SA); drew from students' cultural and everyday understandings (CE); made use of linguistic scaffolding to support students in story-writing (LS)	Students reviewed and interpreted fossil samples; Monica shared that a quarry is where the <i>Flintstones</i> worked; Paula looked up the definition of "quarry" and it to the rest of the class in Spanish and English

**Table 9 (Continued)**

<b>Instructional Day</b>	<b>Features of Instructional Congruency evident in the lesson</b>	<b>Description of the use of instructional congruency in the lesson</b>
<b>Day 6</b> 12/1/2008	<i>[No evidence of IC this day]</i>	Students applied their previous knowledge related to using the metric system to measure fossil samples
<b>Day 7</b> 12/2/2008	Mainly used a student-centered instructional approach to share scientific authority (SA); drew from students' cultural and everyday understandings to discuss tropical climate (CE)	Students reviewed and interpreted fossil samples; related tropic climate to students' experiences in Puerto Rico
<b>Day 8</b> 12/3/2008	Mainly used a student-centered instructional approach to share scientific authority (SA); made use of linguistic scaffolding to enhance meaning (LS)	Students shared their different interpretations of the Tricky Tracks; Monica posted a word-wall in her classroom with recently used vocabulary
<b>Day 9</b> 12/8/2008	<i>[No evidence of IC this day]</i>	<i>[No evidence of IC this day]</i>
<b>Day 10</b> 12/9/2008	Monica mainly used a student-centered instructional approach to share scientific authority (SA); drew from students' cultural and everyday understandings to discuss tropical climates (CE); made use of linguistic scaffolding to support students in note-taking (LS)	Students asked the visiting scientist questions they had prepared themselves; students engaged in making their own interpretation of fossils; Monica and the visiting scientist discussed where similar organisms to the ones that were fossilized can be found today; Monica pointed out the word wall to be used when taking notes and used a poster to describe the environment of the past

**Table 9 (Continued)**

<b>Instructional Day</b>	<b>Features of Instructional Congruency evident in the lesson</b>	<b>Description of the use of instructional congruency in the lesson</b>
<b>Day 11</b> 12/10/2008	Monica mainly used a student-centered instructional approach to share scientific authority (SA); made use of linguistic scaffolding to support students in story-writing (LS)	Students continued identifying fossils; Monica revisited students' graphic organizers for their Tricky Tracks stories and makes references to the "Fossil Fever" book as a text-to-text connection; Monica attributed authority to Raul in terms of discovering that the state was once under water
<b>Day 12</b> 12/12/2008	Monica both challenged and validated student findings to share scientific authority with them (SA)	Students provided rationale for how they identified particular fossils and Monica agreed with them
<b>Day 13</b> 12/15/2008	Monica both challenged and validated student findings to share scientific authority with them (SA); students made use of home language in the classroom (HL)	Students provided rationale for how they identified particular fossils and Monica agreed with them; students used Spanish with one another informally during group-work

also substantiates the following finding observed through video data: *Monica made regular use of instructionally congruent strategies in teaching science and extended regular science learning activities into literacy-developing assignments.*

As described above, selected video segments were transcribed and transcripts were coded for the use of instructionally congruent strategies. These transcriptions were then further analyzed along the lines of which feature of the construct of IC was being addressed. Transcriptions provided evidence of Monica's consistent application of the first construct of IC, the sharing of scientific authority. This can be noted as early as during the second day of instruction in the following transcription (Day 2, October 6<sup>th</sup>, 2008; Lines 261-263):

Monica: ... The title of this book is called the Peteronodon. I hope I pronounced that right. I had to say it little by little because it's difficult for Miss V to pronounce all the dinosaur names. But it's the... how do you say it?

Students: [In chorus] Pteronodon.

Monica: Oh, you guys are familiar. You're better than me. Excellent. I'm going to have to call on you to help Miss V out with that. Now, what do we notice about him. What can he do?

Here, Monica relied on the students to help her pronounce dinosaur names, based on their prior knowledge. In this, not only did Monica validate their prior knowledge, but also positioned herself as a learner within the classroom community.

Further, as described above in her instructional approach, Monica provided time for students to explore fossil samples and opportunities to make sense about what they were seeing on their own terms. During this time, Monica deferred scientific authority to students in terms of what they were seeing and did not correct their evident mistakes. In this way, she allowed them to bring their own understandings into the science learning process. She also invited multiple explanations as to what was occurring across the three stages of the Tricky Tracks scenario (see Figure 2). Through this, she reinforced a collaborative learning environment and attributed content-matter knowledge connections to the students. For example, during a classroom reading session, Monica embedded a comment to relate it to what Raul had said in class the day before (Day 11, December 10<sup>th</sup>, 2008; Lines 169-172):

Monica: "There are specific fossils found in different parts of the US ... looking for signs of sea that was once here"  
And, that was a discovery that Raul made yesterday, that NYS was...

Raul: Underwater!

Monica: One time, underwater...

Here, Raul had scientific authority validated both by his teacher and by outside sources, such as the book. Monica also probed students to consider that there were multiple plausible answers to their questions. In this way, she constructed a classroom environment in which she was no longer the single source of knowledge, but rather, she took on the role of a learning facilitator.

Monica also regularly embedded linguistic scaffolding into her instruction, and she invited the use of everyday language into the classroom. These are both features of IC. Many literacy-building activities were already embedded in her instructional approach, and Monica further adapted science learning activities into writing activities. For example, students wrote fictional stories related to the Tricky Tracks NOS activity. In this activity, Monica emphasized the creative features of science and the different possible inferences that scientists may have given the same data set. Students consistently made use of their everyday and native languages in the classroom, though mostly formal instruction occurred in English. Video records demonstrate Monica addressing particular students in Spanish, as well as inviting students to take notes in Spanish should they choose to. In the following transcription (Day 2, October 7<sup>th</sup>, 2008; Line 309), Monica is explaining classroom instructions to a student with lower ELP:

Monica:      Nosotros estamos haciendo una historia de los dinosaurios.  
                 Estab ... verdad? Ahora, estamos haciendo una historia.... de si  
                 fue un dinosaurio entra .... , okay. Ahora entiende?

This segment literally translates to the following: “We are making a story from the dinosaurs. Were... true? Now, we are making a story... about if one dinosaur entered... okay? Do you understand now?” Though parts of the above dialogue are missing, it nonetheless illustrates the form of instructional support Monica provided

using students' native languages. Through language support, Monica is able to ensure that all students are accessing classroom directions and clarify questions.

Transcriptions of video records also indicate episodes in which students used Spanish while working in their groups.

Monica also demonstrated evidence of incorporating the diverse materials and cultural experiences of students, another feature of IC. For example, when students were discussing dinosaurs in relation to the Tricky Tracks activity, Monica asked them to recall any prehistoric animals of which they were aware. Students relied on everyday cultural knowledge to respond to her question. Raul, in particular, suggests a lemur as an example of a prehistoric animal (Day 2, October 6<sup>th</sup>, 2008; Lines 228-232):

Raul:	A lemur?
Monica:	Pardon?
Raul:	A lemur
Monica:	Those are animals, but to the best of my knowledge, that's not a prehistoric animal. Miss Solis, a lemur is not a prehistoric animal.
Miss Solis:	No, they're in Africa right now jumping all over the place.
Raul:	Why is it in "Ice-Age"?
Monica:	Or, you're talking about the animal that's in that movie? It looks like a lemur. But, it could be... when you make movies, you don't always have to be accurate. You don't have to be accurate about the types of species that are in it.

Through this exchange, it is evident that Raul drew an example from popular culture in response to Monica's question. In turn, Monica asked Miss Solis, the aide in the classroom, to verify his answer. Raul, however, provided further rationale and justification for his response. Given his response, Monica was able to take the cue that Raul was using knowledge based on a recent movie and made a teachable moment out of presenting the imaginative components of movie making. It can be inferred that

Monica was also differentiating between the kinds of information acceptable in movies versus science, given her previous references to “accuracy” needed in science. In this way, Monica framed science in relation to students’ everyday understandings. Moreover, Monica drew on other examples to frame content matter learning. She relied on popular knowledge of the *Flintstones* cartoon to explain a quarry, or the place where the *Flintstones* worked. Another example of Monica drawing from student experiences during instruction can be seen during the visiting scientist’s discussion of climate and locations where fossils can be found. In this transcription (Scientist’s Visit, December 9<sup>th</sup>, 2008; Lines 118-121), Monica connected a portion of the scientist’s discussion with her students’ experiences:

- Scientist: What's the equator like?  
Students: [In chorus] Hot  
Scientist: Hot, humid, right? Rainforesty, right? So, just above the equator, say Florida, Mexico, Caribbean Islands... what is that climate like? [Hot] But, like a beach. You all lay out and tan.  
Monica: Everybody here is familiar with the Caribbean Islands cause most of you have been there. Where, where do you go?  
Brendan: Puerto Rico  
Monica: Puerto Rico, Santo Domingo, right?

In this example Monica connected the instruction to her students’ backgrounds, given that most of the students in her classroom either immigrated to the United States from Puerto Rico or had families there that they visited. In another example, Monica also tied classroom instruction to students’ everyday knowledge and experiences. When students discussed whether a seashell was a plant or an animal, Monica, in turn, asked them to consider the types of seafood they might have eaten. This question engaged other students in the group to contribute their background knowledge to the collaborative learning process. Given this information, students were then able to



deduce that seashells were in fact related to animals, not plants. The following transcription (Day 2, October 6, 2008; Lines 95-105) illustrates this verbal exchange:

- Monica: Remember, did anybody like say whether it's animal or plant? Did anybody identify whether it's animal or plant --that they're looking at?
- Isabel: What would a seashell be?
- Monica: [Does not hear Isabel] Okay, make sure you put that in your notes.
- Isabel: Ms. V, what would a seashell be?
- Monica: A seashell, what do you think it is? When we think about a... you eat anything that comes out of a seashell?
- Paula: Yeah, oysters [jumping in].
- Monica: So what do you think it might be then?
- Paula: Animals or plants [explaining to Isabel]
- Monica: So what would that go under, animal or plant?
- Isabel: Animals
- Monica: There you go.

In line with previous use of this passage, above, Monica's instructional approach validated the student as having determined the answer to her own question.

In summary, this example as well as others presented in this section make the case that Monica did in fact incorporate all features of IC at some time during the course of the Fossil Finders instructional unit. Through this, Monica demonstrates the possibility of science instruction, as framed by inquiry-based instructional activity, to contain culturally congruent practice that may better connect students' everyday and cultural understandings to the activities of science. Monica's sharing of scientific authority with her students demonstrated the potential overlap between the features of IC and inquiry. She used instructionally congruent practice to offset her role as an authority in the classroom and to invite students to co-construct understanding or take ownership for knowledge. This is also related to the use of a SC instructional approach in the classroom. During many instances Monica demonstrated use of

linguistic scaffolding in her teaching; these examples are mainly structured around an application of literacy activities to science instruction. Students' cultural and everyday experiences were also drawn on to help students make sense of science. These everyday experiences oftentimes related to mainstream and popular culture, as further addressed in the discussion section. Finally, though Monica seldom made use of students' home language in the classroom as a part of science instruction, the previously established classroom environment welcomed students to make use of their native languages. Students demonstrated doing so and at times Monica made use of Spanish to assist students with lower levels of English language proficiency. The established regular use of instructionally congruent teaching in this classroom provides the basis to determine how this instructional approach can be combined with inquiry and explicit instruction in NOS.

#### *Explicit Instruction in NOS*

Explicit instruction in NOS considers how a teacher makes the cultural features of science, or nature of science, apparent through instruction. Video data provides evidence of Monica carrying out instruction related to a number of features of NOS over the course of the Fossil Finders instructional unit. These data suggest the trend outlined above: *Monica provided explicit instruction related to certain features of NOS; however, she did not consistently connect classroom activities to the authentic work of scientists.*

Monica's implementation of NOS across the Fossil Finders instructional unit is depicted in the following table (See Table 10.)

**Table 10. Explicit instruction in NOS across the Fossil Finders Instructional Unit**

<b>Instructional Day</b>	<b>Features of NOS evident in the lesson</b>	<b>Description of the how NOS was addressed in the lesson</b>
<b>Day 1</b> 9/30/2008	Science involves human inference and imagination (Inf); Science is tentative (Ten); Science is subjective (Sub)	Monica implemented the Tricky Tracks activity with her students. In it, tracks were uncovered to reveal more “data” about a scenario of the past. Students made and presented their own inferences about Tricky Tracks based on observations. They changed their inferences as more data were presented. Nonetheless, Monica did not make the link between the activity and science obvious.
<b>Day 2</b> 10/6/2008	Science involves human inference and imagination (Inf); Science is tentative (Ten); Science is subjective (Sub) Science is empirically based (EB)	Monica worked with a small group of students and underlined the importance of taking accurate notes as scientists; Monica guided students through the three phases of the Tricky Tracks activity backwards, as an alternative way to come across the data; however, she did not make the link between the activity and science obvious; Students continued to make their own inferences about the Tricky Tracks.
<b>Day 3</b> 10/7/2008	Science involves human inference and imagination (Inf);	Monica differentiated between inferences and observations; Students were instructed to “use [their] imaginations” when constructing explanations.
<b>Day 4</b> 11/17/2008	Science is empirically based (EB); Science is subjective (Sub); Science involves human inference and imagination (Inf)	Monica reminded students that Tricky Tracks stories must somehow incorporate the footprints, or data as evidence; Monica explained “scientists have different stories” and students will be writing their own Tricky Tracks stories; Monica encouraged students to “use [their] imaginations” when constructing explanations.
<b>Day 5</b> 11/24/2008	Science is empirically based (EB)	Students used the tracks on the overhead projector as “evidence” for their Tricky Tracks stories
<b>Day 6</b> 12/1/2008	Science is empirically based (EB); Science is subjective (Sub)	Monica instructed students on how to identify fossils in the rock samples, take measurements of fossils, and enter data into datasheets; The classroom considered “human error” in data collection.

**Table 10. (Continued)**

<b>Day 7</b> 12/2/2008	Science is empirically based (EB); Science is subjective (Sub)	Monica continued instruction related to identifying fossils, taking measurements of fossils, and entering data into datasheets; Students made predictions related to the “Fossil Fever” reading using information presented in the book, which Monica called evidence.
<b>Day 8</b> 12/3/2008	Science is subjective (Sub); Science involves human inference and imagination (Inf)	Students conducted independent work and engaged in writing their Tricky Tracks stories based on the inferences they made about the scenario related to the footprints.
<b>Day 9</b> 12/8/2008	<i>[No evidence of explicit instruction in NOS this day]</i>	<i>[No evidence of explicit instruction in NOS this day]</i>
<b>Day 10</b> 12/9/2008	Science is tentative (Ten); Science is empirically based (EB)	The visiting scientist shared her experiences with data collection and the tentativeness of conclusions that scientists derive, for example “we thought this one was a crinoid and it was a cephalopod!”; Monica engaged students in making fossil observations and measurements and reviewed how to enter data; Monica cautioned students to check each others’ work to “reduce human error” because “scientists make mistakes.”
<b>Day 11</b> 12/10/2008	Science is empirically based (EB)	Students continued the investigation work from previous day; Monica probed students to consider whether they have duplicate copies of the data and what impact this may have on findings
<b>Day 12</b> 12/12/2008	EB; Science is subjective (Sub)	Monica worked with a small group of students to review and confirm their fossil identifications and measurements and stated “we’re doing double-checking. It’s what scientists do, they double-check”; Monica asked whether the group agreed on what they were seeing
<b>Day 13</b> 12/15/2008	EB	Monica continued working with a small group of students to review and confirm their fossil identifications and measurements; Monica asked whether the group agreed on what they were seeing

This table outlines the instructional events in Monica's classroom related to NOS during the Fossil Finders curriculum unit. Monica implemented features of NOS in a variety of different ways. These ways included using the context of the Fossil Finders investigation to position students as practicing scientists and explaining how scientists go about gathering empirical evidence. Further, she used the Tricky Tracks activity to consider the tentative and subjective features of science.

By positioning her students as researchers that are helping scientists, Monica engaged her students in the practices of scientists. This positioning allowed her to consistently compare what students were doing to the work of professional scientists, and justify the tasks she was asking students to do. As described above, transcripts were coded for instantiation of explicit instruction in NOS, and then further analyzed along the lines of which feature of the construct was being addressed. The following transcript (October 6th, 2008; Lines 15-16) provides evidence for Monica's positioning of the students as practicing scientists and justifying tasks based on what scientists do:

Monica: You're going to open up your journals and on the top of the page you're going to write today's date. And, who knows what today's date is? ... Norma...  
It's important as scientists to always keep accurate records and to date all of your entries. Okay? We date everything we do in our class anyway, right? Reading, writing, everything that we do, but specifically as scientists, you need to keep accurate notes and put your date all the time, whenever you do entries.

She reiterated this focus on the practice of scientists throughout the duration of the Fossil Finders unit. For example, when asking students to take notes, she stated that "scientists have to keep accurate notes" (October 20<sup>th</sup>, 2008; Tape MV4; Time 10:33). Additionally, she justified the importance of verifying data in relation to the activities

of scientists. During Monica's collaborative work with groups to review their data, she explained, "we're doing double checking. We might be off, so that's what scientists do, they double-check" (December 12<sup>th</sup>, 2008; Tape MV20; Time 03:36). These examples demonstrate that Monica framed her students as scientists, and justified the activities of scientific practice when it came to careful observation, measurement, and working with data. In this, she also addressed the empirically-based characteristics of science, a feature of NOS.

Monica addressed additional features of NOS, using the Tricky Tracks activity to this end. For example, she made the case that "scientists have the same evidence but different conclusions." In this way, she addressed the subjective and interpretive features of science. For example, in the following transcription (October 6<sup>th</sup>, lines 375-6), Monica explained:

Monica: So, that's what I wanted you to see... different perspectives, different ways that you can view the Tricky Tracks, okay? And I want you to think back, do you remember... there was question [we had] that said: "if scientists all have the same facts, how come they have different theories on what may have happened to dinosaurs?"... If they all have the same facts, why do they have different theories, remember we said it was different stories? This is the perfect example of how we can have the Tricky Tracks, the same facts, the same observation, but yet we are making different inferences, right? Different takes on what could have been. Does that make sense to you?

Though Monica strived to make explicit the subjective nature of science in this lesson segment, her use of the term "theories" as "stories" may be problematic with respect to the literature on NOS. This will be further addressed in the Discussion section.

Monica also addressed the creativity feature of science and emphasized the difference between making observations and inferences. She modeled these differences in the Tricky Tracks activity and continued to apply the terms

“observation” and “inference” throughout the rest of the instructional unit. Students demonstrated evidence of transferring these concepts to understandings about New York State geology by making the inference that their local environment was once covered by ocean water.

However, lesson transcriptions indicate that Monica did not address all features of the NOS construct entirely. For example, through uncovering pieces of data and updating inferences about what is happening with the tracks, the Tricky Tracks activity inherently encompassed the construct of tentativeness in science. Though Monica completed this NOS activity with her students, she did not make explicit the connection between the activity itself and authentic science. For example, she did not point out or ask students to reflect on how their views had changed based on finding new data and how this could be the case for scientists conducting research. Thus, this construct remained implicit in the enacted activity. Consequently, Monica did not tie the classroom activity to this particular feature of NOS. Additionally, though Monica implicitly addressed the socially influenced features of NOS, transcripts do not demonstrate evidence that Monica explicitly referred to science as a socially constructed body of knowledge that is influenced by the culture/s in which it is practiced. This feature of NOS may have been particularly relevant to make explicit to underrepresented students.

In summary, Monica’s teaching touched upon most features of NOS. She emphasized the differences between observations and inferences, the use of imagination in science, and the importance of accurate data through the context of the Fossil Finders project. These focal points address the empirical nature of data as well as the subjective aspects of data interpretation, both key elements of NOS. However, at times Monica could have further tied the classroom activities with the nature of science. For example, when students made different inferences about the Tricky

Tracks footprints, Monica failed to point out that scientists may also have different interpretations based on the same data. This begs the question: what counts as explicitness in instruction with respect to NOS? Further, is there a continuum of explicitness in instruction? To what degree must a teacher be explicit to help students understand about the nature of science? Finally, Monica's teaching did not explicitly touch upon the socially influenced and culturally embedded features of science. The absence of this aspect of NOS in Monica's teaching opened the opportunity to explore and probe students' understandings of how science can be influenced by culture, through interview questions. It also provided a possibility to consider whether students were developing understandings about this aspect of NOS based on learning about the other features, such as the subjective nature of science. For instance, if students began to see science as subjective, then would this influence their views regarding differences in opinion in science given their own bicultural experiences? These questions remain outside the scope of this study however. Nonetheless, the data collected with respect to Monica's instructional approach and the features of NOS her teaching addressed provide important information for considering how her students may appropriate, accommodate, and/or make sense of the culture of science.

#### *Quantification of Features of Focus Constructs Used During Instruction*

The following data and analysis are grounded in the implementation of the Tricky Tracks lesson, which focuses on NOS concepts and serves a background lesson to the Fossil Finders curriculum. The core research questions focus on the added feature of explicit instruction in NOS to science teaching, and the Tricky Tracks lesson is a substantiated activity toward this end. This activity provided a context to observe a combined instructional approach using inquiry, NOS, and IC in Monica's classroom. Data included in this section were selected from a review of all classroom



video transcripts based on the criteria of the Tricky Tracks activity being the focus of instruction or referred to as a part of instruction, which included six instructional days. This analysis is thus anchored to the Tricky Tracks activity and to other instructional moments throughout the unit where Monica used the activity as a basis for other activities, such as story writing. Transcripts of these instructional days were then reviewed more closely for the use of various features of each focus construct in Monica's classroom. Interactional exchanges related to inquiry, NOS, or IC were qualified along the lines of which feature was addressed. These exchanges were marked and then quantified across the construct and the instructional day (see tables 12, 13, and 14).

Table 11 displays how Monica enacted instruction related to Tricky Tracks and its transformation over time, from an activity focused on the work of scientists to a literacy-building activity. Based on this summary at the unfolding of the instruction, it is evident that Monica's instructional approach, which focused on the scientific aspects of the Tricky Tracks scenario, transitioned from an activity modeling aspects of NOS to a fiction-oriented story-writing activity. In this way, Monica is able to present both science-related concepts and also meet her students' grade-level writing requirements. A further analysis was conducted related to transcripts of these instructional days with respect to features of inquiry, IC and explicit instruction in NOS implemented in the classroom, as demonstrated by the tables below.

**Table 11. Tricky Tracks Instruction**

<b>Instructional Day</b>	<b>Nature of Tricky Tracks Related Instruction</b>	<b>Description of Instruction</b>
<b>Day 1</b> 9/30/2008	Tricky Tracks slides and observations; Note-taking	Monica introduced students to the Tricky Tracks slides for the first time; students took notes and made inferences about what they were seeing; these inferences changed as new evidence was presented to students
<b>Day 2</b> 10/6/2008	Tricky Tracks slides backwards and observations; Note-taking	Monica ran through the Tricky Tracks scenario backwards, as if the tracks were uncovered from the last to the first; students connect their prior knowledge about pre-historic animals to the tracks.
<b>Day 4</b> 11/17/2008	Tricky Tracks story-writing as an in-class activity	Monica framed the Tricky Tracks scenario as evidence around which scientists may tell different stories. Students were invited to write their own stories about the tracks. Monica reviewed the components of story writing and encouraged students to use their imaginations related to both realistic and fictional portrayals of what had occurred. Students presented and commented on each others' draft stories.
<b>Day 5</b> 11/24/2008	Tricky Tracks story-writing continued in the latter part of class	Students presented and commented on each others' draft stories
<b>Day 8</b> 12/3/2008	Tricky Tracks story-writing	Students continued to work on Tricky Tracks stories; Monica commented on the need to connect stories back to the actually footprints.
<b>Day 11</b> 12/10/2008	Tricky Tracks story-writing	Monica considers the structure of students' Tricky Tracks stories and the need to use a graphic organizer to plan story writing.

As described above, three of the 13 instructional days were dedicated to the Tricky Tracks activity (Day 1, Day 2, and Day 4), while three more (Day 5, Day 8, and Day 11) extended the lesson into a literacy activity. Transcriptions were completed for any instructional moments during these six days during which any instruction, interaction, or group work revolved around Tricky Tracks. These transcribed segments were then coded for the instantiation of the following constructs: inquiry, instruction in NOS, and strategies of IC, using the coding scheme described in the methods chapter. See Table 5 in the Methods section for coding scheme and the features of the inquiry, NOS, and IC constructs.

The coding scheme is used to determine the frequency and extent to which certain features were being addressed across Tricky Tracks instructional episodes either implicitly or explicitly (Chi, 1997). I marked the instantiation of each of these constructs across conversation turns, or transitions between speakers as described above. For example, when Monica asked her class “And who else thought those might be duck-prints today?” (Day 1, September 30th, 2008; Line 209), this was marked as an instantiation of subjectivity in NOS. Coding the instantiation of features of each construct, in turn, provide aggregate data to consider which features were being used more often than others across Tricky Tracks related instruction. Table 12, Table 13, and Table 14 (below) display data for each construct: inquiry, NOS, and IC. Further, the tables display the combined instantiation of a construct across an instructional day and the combined instantiation of a feature of a construct across the six days of Tricky Tracks related instruction.

**Table 12. Instantiation of Inquiry during Tricky Tracks Lesson and Activities**

	Engage in scientifically oriented questions	Give priority to evidence in responding to questions	Formulate explanations from evidence	Connect explanations to scientific knowledge	Communicate and justify findings	TOTAL
Day 1	6	6	7	6	4	<b>29</b>
Day 2	4	6	1	7	3	<b>21</b>
Day 4	4	1	5	10	1	<b>21</b>
Day 5	0	1	3	1	0	<b>5</b>
Day 8	0	1	1	0	1	<b>3</b>
Day 11	1	1	1	3	6	<b>12</b>
TOTAL	<b>15</b>	<b>16</b>	<b>18</b>	<b>27</b>	<b>15</b>	<b>91</b>

**Table 13. Instantiation of NOS Instruction during Tricky Tracks Activities**

	Tentative	Empirically-based	Subjective	Human inference, imagination, and creativity	Socially and culturally embedded	TOTAL
Day 1	3	5	10	20	4	<b>42</b>
Day 2	5	11	7	11	4	<b>38</b>
Day 4	5	4	4	11	12	<b>36</b>
Day 5	0	1	3	3	0	<b>7</b>
Day 8	0	0	0	0	0	<b>0</b>
Day 11	1	5	5	4	3	<b>18</b>
	<b>14</b>	<b>26</b>	<b>29</b>	<b>49</b>	<b>23</b>	<b>141</b>

**Table 14. Instantiation of Instructional Congruency during Tricky Tracks Activities**

	Sharing scientific authority	Linguistic scaffolding to enhance meaning	Use of students' home languages in the classroom	Diversity of cultural experiences and materials	TOTAL
Day 1	14	17	3	15	<b>49</b>
Day 2	16	19	5	13	<b>53</b>
Day 4	9	15	1	11	<b>36</b>
Day 5	5	6	1	2	<b>14</b>
Day 8	0	2	0	0	<b>2</b>
Day 11	20	5	4	3	<b>32</b>
	<b>64</b>	<b>64</b>	<b>14</b>	<b>44</b>	<b>186</b>

Using this method of quantifying, there were more incidences of using IC than inquiry or explicit instruction in NOS over the course of Tricky Tracks lesson and activities in this classroom. Moreover, NOS-oriented references or practices were more frequent than inquiry-oriented references or practices. These findings are not surprising, given the instructional focus on NOS in this activity. These data also provide grounds to address whether certain features across different constructs were more likely to be grouped together. Based on these tables, it is evident that these constructs were grouped together in the same relative proportion over the primary three instructional days related to Tricky Tracks, Day 1, Day 2, and Day 4.

In terms of the feature of inquiry, Monica and her students most often engaged in connecting explanations to scientific knowledge, or drawing from prior knowledge about science. For example, students made inferences about the environmental conditions in which dinosaurs may have been able to leave footprints, or how these fossils were formed. This inference making relates to scientific principles about rock formation. However, there was less evidence of students engaging in scientifically

oriented questions and communicating and justifying their findings. With regards to the instantiation of instruction circum NOS concepts, the subjectivity of science was addressed nearly a third of the time and nearly twice as any other feature of the construct. The tentativeness of science was the least addressed feature of NOS. In terms of the instantiation of IC, Monica engaged in as much sharing of scientific authority and using linguistic scaffolding. There was the least evidence for the use of native language in the classroom.

These data, combined with the narrative descriptions of instruction in Monica's classroom, provide a more detailed look into the nature of Monica's instruction, across the theoretical constructs driving this research. It is clearly evident that Monica made a concerted effort to use inquiry in her classroom, and she implemented several features of inquiry advocated by the NRC (1996, 2000). However, Monica's students did not engage in one feature of the inquiry—that of an analysis of the aggregate data called for in the curriculum materials of Fossil Finders. This prevented students from further experiencing additional activities authentic to science.

In summary, the teacher, Monica, made regular use of instructionally congruent practice. Her instruction included providing linguistic support and opportunities for students to assume scientific authority, as well as inviting students' home languages and cultures into the classroom. Though Monica taught in a dual-language classroom, she mostly provided science instruction in English. Further, Monica strived to address all of the features of NOS in her teaching through the context of the curriculum unit by framing students as practicing scientists. However, as described above, Monica did not make explicit connections to the social and cultural influences on science. Further, the difference between scientific theories and laws, another aspect of NOS, was not made explicit in instruction. It is possible to question whether or not the curriculum itself provided an opportunity to address these

features of NOS within the scope of the Fossil Finders investigation. These findings beg the following questions: 1) what kind of professional development is necessary for supporting teaching in making all aspects of NOS explicit to their students, irrespective of the curriculum on hand, and 2) what kinds of activities can teachers implement to address the social and cultural influences on science?

Though certain features of the focus constructs may have been less evident than others in this classroom instruction, the instances in which constructs were addressed may still reveal important information about the educational experience of students in Monica's classroom. An analysis combining the three constructs across the Tricky Tracks activity provides a more detailed understanding related to where instructional approaches may overlap. How merging these instructional approaches may influence diverse students' learning and motivation is further addressed in the discussion section. The following section focuses on findings related to students during the implementation of the Fossil Finders instructional unit.

### ***The Experience of Underrepresented Students in the Classroom***

This section presents findings addressing the research question: *What are students' experiences in a classroom implementing an instructional approach that combines inquiry, IC, and explicit instruction in NOS?* These findings shed light on how students from backgrounds underrepresented in the sciences, and their family members, may respond to and interpret curriculum structured around inquiry, NOS, and IC. While these findings connect with classroom science learning experiences, they also may be used to better understand how science instruction may or may not connect to students' everyday lives and cultural understandings outside of the classroom. These findings are displayed in Table 15 below:

**Table 15. Findings Related to Student Experiences across the Fossil Finders Unit**

	<b>Sub-question</b>	<b>Findings</b>
1	In what ways do students engage in inquiry?	Students experienced various features of inquiry through the process of identifying fossil samples, with particular attention to the use of empirical evidence in constructing explanations.
2	How do students bridge their everyday understandings and science in the space of inquiry?	a) Students drew from their everyday life experiences to make sense of science. b) Some focus students viewed school and science content as disconnected from their everyday lives, whereas others made connections between the two.
3	What are students' views about scientific inquiry and NOS, and how do these change during the investigation?	a) Students demonstrated enhanced understandings about NOS as content matter following the Fossil Finders unit b) Students demonstrated changes in their views about science, NOS, and what scientists do following inquiry-based learning experiences and a scientist's classroom visit. c) Interviews with focus students indicated student viewing science as a way of knowing d) Students exhibited preconceived notions about science; some of these views held science and the work of scientists as separate from school science learning; some of these views about science and students' self-identification as scientists shifted as a result of participating in an authentic investigation.
4	What content-matter do students learn?	a) Students demonstrated content-matter learning about fossils and geology in class over the course of the instructional unit.



### *Supporting Data and Analysis*

Data supporting each of these findings is drawn from a variety of data sources, including classroom video, fieldnotes, student work samples, student assessment responses, and informal and formal interviews with students. The data presented in Table 15 above are discussed in further detail below.

*1. Students experienced various features of inquiry through the process of identifying fossil samples, with particular attention to the use of empirical evidence in constructing explanations.*

Video data and analysis of transcriptions provide evidence for students' participation in the activities of science across the lessons within the Fossil Finders curriculum unit. This section makes the case for students implementing various features of inquiry over the course of the instructional unit. However, I do not attempt to quantify or determine the degree to which students engaged in inquiry. Individual lessons were examined for students' use of inquiry using the National Science Education Standards (NSES) for inquiry (NRC, 2000), which serve as the guiding principles of the coding scheme used for data analysis (Table 5). Instructional episodes identified as those demonstrating student participation in inquiry were qualified along the lines of which feature of inquiry the episode addressed. Representative examples of students engaging in various features of inquiry are included in the narrative below. These examples were selected based on video and audio quality; the transcript segments included below are thus drawn from video recordings with clear enough audio quality to differentiate individual voices in group settings.

The first feature of inquiry deemed essential to science learning by the NRC requires that learners are engaged in scientifically oriented questions. According to the NSES, scientifically oriented questions “center on objects, organisms, and events in the natural world... they are questions that lend themselves to empirical investigation, and lead to gathering and using data to develop explanations for scientific phenomena” (p. 24). Within the context of the Fossil Finders project, students demonstrated engaging in both the pre-determined research question guiding the investigation and the questions about science and scientific content matter that precipitated from students’ involvement in the curriculum. Students engaged in posing their own age-level appropriate questions within the scope of the greater study. For example, within the context of investigating fossils, students questioned whether clams were plants or animals (see transcription above; Day 2, October 6, 2008; Lines 95-105). These questions might have fostered separate empirical investigations by the teacher or her students.

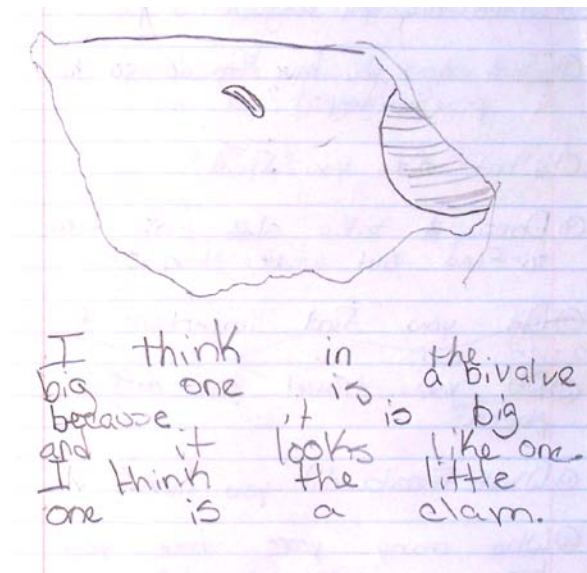
Another feature of inquiry includes connecting explanations to scientific knowledge. Data analysis related to classroom context indicates that, of the five features, this one feature of inquiry was most often identified across transcriptions related to the Tricky Tracks activity of the Fossil Finders curriculum in Monica’s classroom. As described above, this included connecting explanations to age-level appropriate content-matter understandings. For example, if local fossilized organisms were clams, then there must have been a body of water present in which they once lived. These connections to scientific knowledge were directed by the teacher through scaffolding or these were generated by students themselves. For example, Monica probed students to consider reasons for the dinosaur tracks in the Tricky Tracks scenario based on students’ knowledge of dinosaurs, their behavior and need to survive, and the environment (September 30<sup>th</sup>, 2008; Lines 135-146):

- Isabel: Um, the two dinosaurs ... they saw each other, so they um... are running around chasing each other.
- Monica: They're running around chasing each other... if dinosaurs are running around chasing each other... from past... from books that we have read, because we have, like Isabel has pointed out, Miss V has a bin of dinosaur books for you to read. What do we know from the past reading about dinosaurs? If they're running around chasing each other, what can you infer? Um...
- Norma: Fighting?
- Monica: Fighting? Who thinks they might be fighting? [Students raise hands] And, if they're fighting, what do you think they might be fighting over? [Students enthusiastic to respond] What do you think they might be fighting over, Jorge?
- Jorge: Their food?
- Monica: Food, most likely food . So, if there was food there, what type of area do you think that might look like? If they were all... if they both were heading out to that area to forage for food...to get some food, what do you think that area looked like?
- Bianca: Muddy with a lot of trees ?
- Monica: [murmur] Muddy with a lot of trees, okay. What do you think?
- Isabel: Maybe and a lot of animals.
- Monica: Maybe there were animals there to eat.
- Paula: Maybe there was a river or a lake...
- Monica: River or a lake, and what else?
- Paula: ...and there was fish
- Monica: And there was fish for them to hunt? Okay. So, now you should be able to draw what you think might be there and why both of those dinosaurs were heading that way.

Students used evidence to construct these explanations; however, these explanations are age-level appropriate scientific knowledge and principles. Students further used these explanations to make inferences about the Tricky Tracks scenario. For example, students were able to connect their understandings of dinosaur tracks moving in search of food and perhaps in relation to a fight. Moreover, students considered how the tracks may have been left in muddy grounds, which would indicate water in close proximity. Building upon this collective case making scenario, students then proposed that fish may have been the dinosaur's food-source. In this case, students

demonstrated connecting their explanations to scientific knowledge with Monica's probing. These student generated connections may be illustrative of students mediating between everyday ways of knowing and science as well. For instance, it is not possible to determine where students learned information about dinosaurs. However, it is probable that this knowledge is related to mainstream culture or popular understandings about dinosaurs, not classroom learning.

Further features of inquiry include: giving priority to evidence in responding to questions, formulating explanations using evidence, and communicating and justifying explanations. In the following notebook entry, Alyssa, one of the focus students, drew an illustration of what she is seeing, or her observations, and provided rationale for the inferences she made. Though there is room for more elaboration in her rationale, Alyssa was nonetheless demonstrating that she is beginning to use evidence in formulating her inferences and to communicate and justify her thinking.



**Figure 3. Illustration from Alyssa's Notebook, December 9<sup>th</sup>, 2008**

In another example of students independently making use of features of inquiry within the context of the instructional unit, students provided evidence-based rationale to explain how they determined the kind of fossil they had identified when Monica was verifying the data students had collected. Video data illustrates this particular group's use of evidence in formulating their explanations and how they communicated their findings to the teacher and the researcher (Xenia) in the following transcript excerpt (December 12<sup>th</sup>, 2008; Lines 558-575):

Monica: What did you find?  
 Alyssa: Um, a brachiopod  
 Renee: Fragmentation of a brachiopod  
 Monica: Let me see; your eyes are better than Miss V's. What makes you think it's a brachiopod? Look at your identification chart.... What do you think, Xenia? I'm thinking it might have three, I don't know  
 Xenia (Researcher): I think it's a brachiopod, too.  
 Monica: My eyes are bad, Miss V's eyes are bad. I have to get my glasses. That would help! [*Monica gets up to get her glasses on the other side of the room*]  
 Xenia (Researcher): I want to ask you girls why you thought it was a brachiopod.  
 Alyssa: Cause, like right here it's like this and like that  
 Renee: It's fragmentation  
 Xenia (Researcher): It's fragmentation? But why... how do you know it's not a clam?  
 [*students learning in; shifting papers*]  
 Nelia: It doesn't look like it.  
 Renee: [*gesturing patterns with hands*] A clam goes like this... and I think it would be like this...  
 Xenia (Researcher): Okay  
 Renee: You can see the half of the heart  
 Xenia (Researcher): Okay, I think that's a great reason  
 Renee: See, like this part is shaped like this part right here. [*demonstrating*] And this part is like half of the symmetrical shape of the brachiopod.

Xenia                      And you all agree, or do you disagree?  
(Researcher):  
Group:                      We all agree

This segment demonstrates students basing their explanations with supportive evidence from the fossil itself. It also shows students determining what they were observing and providing rationale. For instance, Renee explained that the brachiopod was shaped in a particular way. Further that it was broken, using the terms “fragmentation” and half of a “heart.” The students were guided by the teacher to communicate their explanations, with some probing from the researcher.

Nonetheless, students were able to explain and justify their rationale. For example, Renee built on her explanation of the fossil looking like a heart to describe her reasoning using scientific terms. “This part is like half of the symmetrical shape of the brachiopod” (Line 573). With this response, Renee elaborated upon and justified her original response to her teacher’s question.

This scenario also illustrates an instructional episode that addressed several features of inquiry, such as using making use of evidence when constructing an explanation. It also provides evidence that students engaged in these features along a continuum, as there are varying degrees of involvement in inquiry. For example, students may be involved in particular features of inquiry at a surface level more congruent to everyday ways of knowing— or at a deeper level more congruent to authentic science. In the example above, Renee readily provided a response to her teacher’s question, using evidence for her explanation using everyday examples. However, it was also the researcher’s probing that lead Renee to provide a more in-depth response and justify it using scientific terminology. In this way, this classroom setting was demonstrative of the possibility to implement the various constructs of inquiry at different degrees. These data capture the dynamics within one group and

the case of one particular student in a group setting. It is not possible to generalize this finding for all students in the class. However, Renee's example brings other considerations related to data collection and to student understandings to light. With respect to data collection, Renee demonstrated more in-depth understandings when probed. This may suggest that unless probed, students may have not elaborated on their reasoning. Consequently, data collected with respect to student groups may not completely demonstrate students making use of evidence to explain a particular agreed upon piece of data.

Additionally, this episode demonstrates that not all features of inquiry may occur during a single instructional segment. Though students were involved in working with data and explaining their responses, they were not engaged in connecting these explanations to other scientific knowledge in this particular instance. Over the course of the instructional unit, examples can be found to depict each of the features of inquiry, again along a continuum. The instructional episodes presented in this section illustrate exchanges between Monica and her students that are examples of students engaging in features of inquiry and representative of other interactional exchanges over the course of the Fossil Finders unit. The purpose of presenting these data is to establish that students did, in fact, engage in certain features of inquiry and to illustrate what this looked like in Monica's classroom. These data indicate that students did indeed, engage in features of inquiry within the context of the Fossil Finders unit. Further findings consider students' learning experiences in this instructional setting.

#### *2a. Students drew from their everyday life experiences to make sense of science*

Video transcriptions of classroom instruction show evidence of not only Monica drawing from everyday life examples to talk about science, but also students

using everyday knowledge to make sense of science instruction. Moreover, coded transcriptions of instruction related to the Tricky Tracks activity (Table 12) indicate that students were most engaged in the inquiry feature of connecting explanations to scientific knowledge, or using their prior understandings about science to explain their responses. Students needed to use their prior scientific knowledge about animal behavior and the conditions under which tracks are laid to make inferences about what had occurred across the Tricky Tracks slides (Figure 2). The two bodies of data described above suggest that students attempted to bridge the space between school science and their everyday lives in the classroom. The following examples provide evidence for this claim.

During the initial segment of the Tricky Tracks activity on Day 1, Monica asked students to take notes and reflect on what they thought was occurring based on observing the tracks on the slide. I moved around the room with the video camera and in addition to the teacher, I asked students what they thought was happening in the scenario. Students inferred or posed that they were seeing a variety of organisms' footprints, including those of an iguana, chinchilla, crocodile, squirrel, and more. Because Monica did not provide background instruction related to organisms and their footprints, students could only make inferences based on their previous. In response to the question, "what do you think you're seeing there," Bianca, one of the focus students, explained her thinking about the scenario and provided rationale. She decided that she was seeing prints of animals she was familiar with. She stated "raccoon footprints and a duck. I think it's raccoon because it looks similar to a book I read and I think it's a duck because I've seen duck tracks before from a duck in the sand" (Day 1, September 30th, 2008; Line 61). In this statement, Bianca built on her prior and everyday understandings to make sense of the classroom scenario. Because Bianca had engaged in reading, which most likely included illustrations, she made an



inference about seeing raccoon tracks. Because she had seen actually duck prints in the past, she was able to make an inference about seeing duck prints on the overhead projector slide. This example thus illustrates how Bianca was able to bring her prior knowledge based on everyday experiences into making sense of science.

In an example illustrated above, students were discussing dinosaurs in relation to the Tricky Tracks activity. Monica then asked them to recall any prehistoric animals they were aware of. Students relied on prior knowledge to respond to her question and verbalize a list of animals. These animals included saber-tooth tigers, woolly mammoths, and the *Tyrannosaurus rex*. Raul, however, suggested a lemur as an example of a prehistoric animal and drew justification from everyday life to explain his reasoning (see Transcription, Day 2, October 6<sup>th</sup>, 2008; Lines 228-232). When Raul provided further rationale and justification for his response, Monica was able to take the cue that Raul was using knowledge based on a recent movie he saw. This example ties back to the instructional context that Monica established in her classroom and the use of student knowledge to introduce concepts related to science.

In another example toward the end of the instructional unit, Monica reviewed the fossil samples with a group of girls. During this time, Monica confirmed each piece of fossil data entry and students' measurements. This was a part of Monica's way of reinforcing the concept that "scientists take accurate notes." The students in this group were familiar with the rocks in the sample that they studied and discussed them with Monica in the following transcript segment (December 12<sup>th</sup>, 2008; Lines 546-552):

Monica: We're going to go through all the rocks.  
Did you find anything here?  
Girls: Yeah!  
Monica: Okay, what was that?  
Nelia: A clam?

Renee: It is.  
Alyssa: I think it looked like a this [picks up an actual clam shell]  
Monica: A clam? Okay, let's go to the clams. ....

In this exchange, Nelia took a tentative guess related to identifying a fossil. This is evident through her questioning tone and inflection in her voice. Meanwhile, Renee affirmed Nelia's response with certainty. Alyssa, however, drew from an object in the classroom to explain her response. It is not clear whether Alyssa may have been aware of what a clam was prior to classroom instruction, but she demonstrated making a connection between an everyday classroom object and the scientific sample she was viewing with her group. Alyssa's example is also illustrative of students making sense of science using everyday understandings. It is also evidence of some collaboration and consensus building between the teacher and the students.

These various incidents point to how students in this classroom used previously established knowledge to make sense of science. There is additional evidence of Monica facilitating students making connections between the content-matter and their everyday understandings. For example, in explaining that a quarry was a place where the *Flintstones* worked, students also brought everyday understandings into the classroom space. These everyday understanding were thus integrated into science learning within the context of this classroom.

*2b. Some focus students considered school and science content as disconnected from their everyday lives, whereas others made connections between the two.*

Interviews conducted with focus students pointed to differences in what students learn in science class and what they identify with as a part of their everyday lives. Three of the five focus students indicated that school science learning did not

extend beyond their classroom learning experiences. The two other focus students indicated areas in which content-matter learning *can* in fact apply to their everyday lives. These responses reveal how certain students made these connections and considered the relevancy of science outside of the classroom setting. In light of the findings described above with respect to students' use of everyday understandings to make sense of science, it is interesting to take a closer look at these data in an attempt to ascertain how to support students in making connections with their everyday lives.

In this classroom, school science introduced certain students to new content-matter and built on the prior experiences of others. For example, Paula voiced that she saw fossils for the first time in her life. Bianca, however, connected with her previous experiences with fossils, "one time I picked one up and there was a shell-shape in it." Though she had seen fossils before, she had limited knowledge of them. She followed up her comment by situating school as a place to learn more about science content-matter with the statement, "my parents don't know a lot about fossils and I can learn it here." Raul also mentioned having found fossils before and having seen them in a museum. In these examples, these students indicate ways in which science learning may be new to them or may connect to their prior experiences outside of school settings.

Further interview questions probed students how on their views of how what they learned in class may relate to what they do outside of school. In their replies, focus students commented on similarities and differences between classroom science learning and their experiences with science in out-of-school settings. Paula described science content-matter learning as being bounded by the classroom setting. Paula stated, "at home, rocks don't look like fossils." In this sense, what Paula learned remained framed by the classroom setting. Raul, however, considered the purpose of learning across settings for the future, stating "if you find a rock you can describe it."

In an interview, Bianca described that she wanted to become a vet in the future. For Bianca, “science connect[ed] to everyday life because there are fossils everywhere” and learning about fossils was learning about different kinds of animals. Together, these responses are evidence of students making connections between school science learning and their lifeworlds, framed by the context of an authentic investigation, where students participated in the activities of science. Further research is needed to consider the factors contributing to students’ abilities to make connections between school, science, and home worlds, and how this contributes to relevancy in science instruction. However, this remains beyond the scope of the current study.

*3a. Students demonstrated enhanced understandings about NOS as content matter following Fossil Finders instruction*

Focus student interviews and results on a pre-post measure indicate emerging understandings about NOS. Interviews were conducted between the first and second iterations of the pre-post measure, where students were tested on their changing views about NOS using the VNOS-E instrument. These questions assessing knowledge of NOS were embedded into the pre-post assessment students took in Monica’s classroom prior to the start of the Fossil Finders curriculum and upon its completion. As described in the Methods section above, the first 14 questions of the pre-post measure assessed with geology-based content matter, while the second portion included short-answer response questions taken from the VNOS-E. Students were assessed in a post-post test design using the VNOS-E four months later to determine evidence for retention.

As described above, the VNOS-E aims to assess students about their understandings about NOS. This includes understanding these aspects of NOS: science as tentative, empirically-based, subjective, involving human inference, and

socially and culturally embedded. Analyses of the pre-post test and post-post test measures for five focus students indicate a shift from naïve views about science and NOS to emerging or partially informed understandings about science and NOS. These more developed views map on to what is a continuum of understandings related to NOS, from uninformed to emerging to informed. The following student responses to questions on the VNOS-E represent changes in content-matter and in understandings about science. These data contain the original spelling and syntax of students and may be indicative of differing levels of academic English language proficiency.

The first question of the VNOS-E asked, *What is science?* Focus students in Monica's classroom responded to this question on the pre-test along the lines of viewing science as subject-matter in school, science as a way to find out about things, science as making progress, and science as reading a book (Table 16). For example, Alyssa initially described science as "a fun subject" and Bianca described science as "things that help you find out about" a variety of phenomena. Raul, on the other hand described science expansively as "progress" and also very narrowly as something that you "learn from a book." Post-test responses show enhanced understandings of the processes of science and of the active role of the scientist in observing, analyzing, and making inferences. For Alyssa, her initial response shifted from describing science as subject to considering scientific processes, such as when you "try to figer out things, to observe, to anylise and to infer" [sic]. She also connected the study of science with the discipline of earth science. Bianca elaborated on her understandings of scientific processes and also extended science to studying about dinosaurs. Raul wrote that science has to do with an interest in learning more about something. The retention-test responses indicated that students mostly retained these views four months after completing the project. For example, Alyssa wrote that science is "when you observe

and inference” and included her pervious reference to studying the earth. Bianca wrote specifically, “it is about making inferences, observations.” Raul’s response had to do with the empirical nature and processes of gathering data.

**Table 16. Focus Student Responses to VNOS-E Question 1: What is science?**

	<b>Pre-test</b>	<b>Post-test</b>	<b>Post-post Retention Test</b>
Alyssa	Science to me is a fun subject because you can learn and do a lot of projects.	Science is when you study about the earth and do expirimets, try to figer out things, to observe, to anylise and to infer	Science is went you study about the earth and pre-historyc time and when you observe and inference
Bianca	Science is like things that would help you find out about the solar system, gravity, you can find out about the moon, the milky way and lots of cool projects.	Science is about observing, making inferences, figuring out expiraments, and things that lived millions of years ago (dinosaurs)	Science is about studying the earth, fossils, archiology, and paleontology. It is about making inferences, observations, and learning about prehistoric times. Also you learn about the climates there was and then NYS was underwater with the trilobite and brachiopod
Raul	Making prograss read about science book and lear what science is	I think that science is somein when some boday findes fossil and leardes aboutet them and loveing wahat you do	science is a very cool thing I like looking a fossel reiting down what you read what you looked at

It is important to note that all three students moved from demonstrating having broad views about science to context-dependant views on science. For example, though the pre-test responses have nothing to do with geology or fossils, in their post-test responses, all three focus students made reference to science as studying about the earth, dinosaurs, or fossils. The retention test responses were yet further

contextualized by the project. For example, both Alyssa and Bianca referenced pre-historic times, while Raul wrote about observing fossils. In this way, these responses were also indicative of student understandings about science being contextualized by the Fossil Finders curriculum unit.

The second question probed student understandings about the use of evidence in science and asks, *How do scientists know that dinosaurs once lived on the earth?* In her pre-test response, Alyssa wrote “Because they study a lot to know these things.” She thus attributed scientific knowledge to an academic realm. Her retention-test response, however, indicated the use of empirical evidence to construct explanations in science. She wrote “because they can see the tracks and in the rock you have prove that there were dinosaurs and they can see the prints.” Though her notion of “proof” or evidence in science is naïve, the difference between her responses demonstrates a more informed understanding about how science is practiced and the role of scientists in constructing scientific knowledge.

The third question probed student understandings of the subjectivity of science and asked, *How sure are scientists about the way the dinosaurs looked?* Two of the focus students’ responses needed a closer look (see Table 17 below). In her pre-test response, Alyssa made reference to scientists possibly having seen the dinosaurs. However, her post-test response made use of evidence, such as fossils, as rationale for scientists being certain about how dinosaurs looked. Further, her retention test indicates content-matter understanding and hints at the subjectivity of science. Here she wrote about scientists being certain about the bone structures but not the skin. It can be inferred from her response that scientists are not certain about what the skin actually looked like, despite book illustrations and other images of dinosaurs they’ve seen. Brandon, however, consistently made reference to dinosaur bones and then later, fossils, as he described the certainty of scientists when it comes to what

dinosaurs looked like. Brandon's response to the same question on the retention test was indicative of his understandings about the tentativeness of science and possibility for human error.

**Table 17. Focus Student Responses to VNOS-E Question 3: How sure are scientists about the way the dinosaurs looked?**

	<b>Pre-test</b>	<b>Post-test</b>	<b>Retention Test</b>
Alyssa	Maybe some scientists swall they dinosaurs	Very sure because they have seen the Fossil and they are sure because they now when the study about back then.	I think there are very sure because if they put the bones together you can see how they looked but with out the skin
Brandon	cuse scientists studied on the bones and the found the now what dinosaur looked like	scientists know about the way dinisaur look. The research is to help them figure out what dinosaur it is. When the scientst found all the bones and put them all toghether. Then they now what dinosaur it is.	Very shure. The way that they now is by connecting the right fossils together. But everyone makes mistakes.

The following VNOS-E questions also probed for student understandings about the subjectivity of science: *A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists have all the same facts about dinosaurs, then why do you think they disagree about this?* Alyssa explained the disagreement between scientists as having to do with what scientists know in her pre-test response. "Because some scientists know different things." However, her post-test and retention-test responses were more indicative of differing opinions, rather than knowledge, that scientists may hold. Her post-test and retention-test responses, respectively state the following: "They may have different opionoin because they saw diferent thing" [sic] and "I think that they disagree because they may know something diferent of they may have different opinion" [sic]. These statements are indicative of



Alyssa coming to understand the subjective nature of science and that the opinions of scientists may drive some of the conclusions that they make.

This VNOS-E question is directed toward student understandings of the creativity, and inference-making, used by scientists in constructing explanations: *Do scientists use their imaginations when they do their work?* In response, Bianca first wrote, “I think they don't [use their imaginations] because scientists really do dig up things like dinosaur bones, reptiles, mamoths, and lot of others” [sic]. This response illustrates Bianca’s understanding of science as strictly data-based, without an interpretive component. Bianca made a shift in her post-test response toward the human aspect of science, including the use of imagination as a part of science. For example, she wrote “I think they use their imagination when they find new animals and they imagine what they would look like.” The post-post test points out that Bianca retained this view and framed it within the context of paleontological work. She wrote, “I think they use their imaginations when they learn about prehistoric time and when they study fossils.”

In response to the question *Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?*, Bianca first wrote about how current understandings may shape future knowledge. “Yes, because in our invironment we now have different animals and some might extinct in the ground” [sic]. However, her post-test response pointed to the tentativeness of science through the type of data that’s available. “Yes, because might not have been able to find full fossils with brachiopods and in the future the probably will.” In this response, Bianca demonstrated more developed views about NOS in that she considered the empirical nature of science and the tentativeness of scientific knowledge.

These shifting responses across the VNOS-E measure indicate student development towards more informed views about NOS through their involvement in an authentic investigation. Though their responses may not include robust understandings about NOS, they reveal that students are poised for future learning with respect to understandings about NOS. It can be assumed that an understanding that science is subjective may later prepare students to understand the cultural differences of science across the places where it is practiced. These ideas will be further considered in the Discussion section.

*3b. Students demonstrated changes in their views about science, NOS, and what scientists do following inquiry-based learning experiences and a scientist's classroom visit.*

Interviews with the five focus students indicate shifting views about science, NOS, and what scientists do following involvement in inquiry and an opportunity to interact with a scientist. Students were first interviewed on December 8<sup>th</sup>, 2008, using an interview protocol focused on gathering their views about science and their everyday lives (Appendix H). These interviews provided baseline data of student perceptions about science in relation to school science learning and how students made sense of everyday phenomena outside of school. Though the VNOS measure (Appendix G) also provides important information with respect to students' understandings of NOS, the interview was structured using a perspective focused more on home and cultural understandings about science. Further, students had opportunities to elaborate on how their views on what scientists do and NOS were influenced by their learning experience in the classroom. In this way, interview responses serve to triangulate the VNOS measure and also reveal greater details about students' perspectives about science. Follow-up interviews were conducted with

students on December 15<sup>th</sup>, 2008, after engaging in the initial portion of the Fossil Finders investigation and interacting with the visiting scientist the previous day. These interviews followed a narrower script that focused more on what students thought about science in relation to their experience with the investigation and the scientist's visit (Appendix I). Analysis of these interviews revealed the focus students' changing views on what science is and how it is practiced.

For example, in her first interview, Alyssa mentioned liking science and wanting to become a doctor for babies. However, in the second interview upon completing data collection and analysis, she commented on the fact that fossils are fun and that she used to think that science was learning out of a book. Bianca first mentioned that she wanted to become a veterinarian and acknowledged that there's "a lot of stuff that's involved has to do with science" in that field. However, upon being involved in a fossil-related investigation, Bianca acknowledged that fossils can teach you about what animals were around a long time ago and stated that she now wanted to become a paleontologist. She also commented on her changed views about science in her follow-up interview and the fact that "before, [she] thought science was about experiments and gadgets."

Brendan's second interview indicated a shift in his understanding what scientists do. For example, in his first interview, he commented that scientists do things differently, based on the discipline they represent. This would be the case of chemists and physicists. After completing a geology-based investigation, he stated the following: "I thought scientists used chemicals and experiments, but they do more than that." While Brendan hopes to go to a police academy in the future, he thinks "fossils are really amazing" and "meeting a scientist for the first time was very special." Raul, as well enhanced his understandings of the work of scientists. He moved from a perspective that science is all about being "hands-on" to a deeper

understanding about science. He mentioned that it was “really cool to meet a scientist” and that “she could tell us a lot of stuff that we didn’t know.” This comment suggests that for Raul, science becomes more than a practiced school activity, but a body of knowledge that goes beyond the walls of the classroom. Raul also broadened his perspectives of what scientists do, as revealed in his follow-up interview. His views expanded to reframe science being beyond a school subject, but rather, diverse ways of learning about different things. As Raul stated, “different scientists study different kinds of things.”

These student comments indicate a shift in perspectives about science and what scientists do upon engaging in an authentic investigation and interacting with a practicing scientist. The changes in student perspectives coming out of the intersection between students’ school-worlds of science and the practices of actual science are illustrative of the potential for engaging underrepresented students in science learning through this instructional approach

### *3c. Interviews with focus students indicated students viewing of science as a way of knowing*

Interviews conducted with five focus ELL students related to their views on science indicated these students were beginning to understand the tenets of NOS-- that science is tentative, based on evidence, subjective, and involves human inference. The above finding is based on evidence from my journal and running notes of student responses to preliminary interview questions on December 8<sup>th</sup>, 2008, and follow-up interview questions, on December 15<sup>th</sup>, 2008. Examples of student responses to interview questions to support this finding are included in the text below.

In response to the question “do all scientists do science the same way?,” all five focus students indicated that scientists did not do science the same way, but rather

did different kinds of work. For example, Bianca responded “sometimes a scientist might do experiments and sometimes a scientist might do fossils,” indicating an understanding that not all science is experimental. Brendan also commented on learning that scientists did other things than “experiment with chemicals.” Raul acknowledged that some “scientists learn from past and figure out fossils” but others “might be learning about something else.” Meanwhile, Paula commented “scientists have different stuff to do” and explained that scientists discover new things and have different pieces of data to support their discoveries. These views on science indicate emerging informed views about the diverse practices and fields of study that scientists may engage in and that science is a dynamic process, rather than an established set of facts.

In response to further questions, “do all scientists agree?” and “do all people agree with scientists?” student replies indicated differing, yet emerging informed understandings about the tentativeness and subjectivity of science. For example, Brendan stated, “scientists have imaginations and disagree sometimes.” This response considers scientists as active agents of constructing explanations based on their subjective perspectives. Paula also explained that sometimes scientists agree and sometimes they do not. This is because “scientists aren’t the same.” Moreover Paula stated that “people don’t always think scientists are right,” which begins to consider the positionality of science in relation to other ways of knowing. Raul suggested that sometimes scientists take guesses, for example, “if they’re looking at a brachiopod or some other type of fossil.” This suggests that viewpoints in science may be tentative. Raul also stated, “people don’t always agree with scientists” but that “some people aren’t right because they don’t know more than the scientist.” In this response, Raul positioned scientific knowledge as contentious and also possibly having authority over other ways of knowing. Like Raul’s statement, Bianca’s response to the first question

also suggested possible disagreement amongst scientists while interpreting data samples. “Somebody might think it’s a segment of a brachiopod and another one doesn’t. For instance, one scientist thinks it’s this and the other thinks it’s that.” However, home-based views shaped her understandings that not all people agree with scientists. Bianca explained, “one time I was at home and my brother started talking about scientists and what they were doing and my dad said that they were wrong and that not all people agree with scientists and what they do.” In this statement, Bianca positioned scientific knowledge as not always having authority, based on family views. These statements illustrate student views of the tentativeness and subjectivity of science in relation to their understandings about science and everyday lives.

Together, these interview responses indicate students viewing of science as a particular way of knowing, rather than solely content-matter. While some students demonstrated the ability to connect science processes and content with their everyday lives, others considered how science remained apart from their day-to-day lives. With these understandings, it can be argued that students may begin to consider how their everyday and cultural understandings may or may not align with scientific ways of knowing and the importance of making NOS explicit to students through instruction. Student responses to interview questions are also indicative of focus students having some understandings related to the diverse approaches used in science and features of NOS. For example, students commented that scientists used various approaches to go about their work, that science included interpretation and inference-making, and that scientists possibly disagreed on what they were finding. Moreover students shared views that people did not necessarily always agree with scientists, though for different reasons. Across these interview responses, students did not yet hold understandings related to the socially and culturally embedded features of NOS; yet their preliminary

understandings of the tentative and subjective aspects of science may indeed, prepare them to consider science across different cultural spaces in the future.

*3d. Students had preconceived notions about science; some of these views held science and the work of scientists separate from school science learning; some of these views about science and students' self-identification as scientists shifted as a result of participating in an authentic investigation.*

Interviews with focus students demonstrate that students had preconceived notions about what science was and what scientists did based on classroom learning experience and other outside experiences. As in the previous section, this finding is based on evidence from my journal and running notes of student responses to preliminary interview questions on December 8<sup>th</sup>, 2008, and follow-up interview questions, on December 15<sup>th</sup>, 2008. Student responses to interview questions in support of this finding are included in the paragraphs below.

Notions about “real” science were mostly separate from understandings of school science and science learning. Students, however, were more likely to bridge understandings about science content-matter learning rather than processes across settings. These views shifted through participating in classroom activities related to the investigation. Moreover, while students self-identified themselves as scientists following participation in the project, their views of what scientists actually did were ultimately shaped by their classroom experiences. For example, many students were able to describe the processes of data collection, however, were not able to describe how scientists made use of data.

Students held particular perceptions about science prior to engaging in an authentic investigation. For example, in her first interview, Paula stated, “science is about learning most of the stuff your teacher says.” But she also commented on the

differences between “regular science” and the investigation she was participating in. “Fossil Finders is different from regular science because in Fossil Finders you have real fossils but regular science you learn from book.” In her reflective interview, Alyssa also commented on her changed views about science along a similar vein. “Before we started working on fossils, I thought science was reading out of a book.” Both of these students reflected on school science learning in their responses. Thus, these responses suggest that students may or may not be connecting their school science learning to other notions about science outside of school. Bianca, however, considered the scientific enterprise in her response. She stated, “before, I thought science was about experiments and gadgets.” After participating in the investigation and meeting a scientist, she announced “I want to be a paleontologist.” These changing views indicate initial perceptions about school science learning, as well as the scientific enterprise.

Students’ lack of interconnectedness between their views about school science learning and the scientific enterprise may be indicative of infrequent instructional links between the two. Nonetheless, Alyssa commented on the similarities of the purpose of science across settings. In her response, she stated “science is similar to life because you discover new things every day.” This sense of discovery may or may not encompass the processes of science, as related to inquiry; however, it can be inferred that this statement differentiates the processes of discovery from traditional classroom science approaches based on Alyssa’s statement in the paragraph above. In this sense, she commented on the processes of learning, rather than science, in both settings.

Student responses to interview questions shared above also demonstrate that students had preconceived notions related to what scientists do. For instance, Alyssa claimed that “scientists discover new stuff,” and needed to “observe it, feel it, learn about what is it” to this end. As described above, Bianca first held views that



scientists have to do with discovery, mystery, and experiments. Bianca then described, “a scientist might do experiments and sometimes a scientist might do fossils.” It can be inferred that in her latter viewpoint, Bianca referred to geological research as non-experimental science. Brandon expressed similar sentiments across his interview responses. In his first interview, Brandon shared “scientists do experiments with chemicals, invent.” However, in his second interview, he stated, “I thought scientists used chemicals and experiments, but they do more than that.” Raul claimed that there were different types of scientists, altogether. For example, while “scientists learn from past and figure out fossils, some [other] scientists might be learning about something else.”

Students identified with also *being* scientists upon participating in the investigation when asked “would you describe yourself as a scientist?” However, reasons for describing themselves as scientists differed across students. Brendan, for example, self identified as a scientist because he “has a notebook like a scientist” and took notes. Raul, however, provided rationale for describing himself and the rest of the classroom as scientists for the reason that they were all involved in an investigation. “We’re basically doing the same thing” as scientists, he stated. Though in her first interview, Bianca honestly stated that she was not a scientist because she was “not that good at science,” in her reflective interview she identified with wanting to become a paleontologist, as described above. Like Raul, Paula also felt that she was a scientist; however, there were inconsistencies in what she thought scientists did and what she did to solve problems. For example, while she thought scientists “discover new stuff,” she explained that when she tries to figure out a problem, she does so by “using internet or an encyclopedia.” Her response does not entail the production of new knowledge; rather, it relies on sources of information for already determined facts. Though all focus students identified with being like a

scientist, interview responses also indicated that the work of scientists remained largely obscure to them, as in Paula's case above.

It is evident that students largely based their notions of what scientists did on their classroom experiences of observing and identifying fossils based on these interview responses in comparison to classroom instruction. As described earlier, students sorted through fossil samples, identified, measured, and recorded fossil data during the instructional unit; however, aggregate data analysis was not part of the instructional focus in Monica's classroom due to the lack of time. Student responses to interview questions indicated that while students understood the observational aspects of science, they were uncertain of what scientists did with data once it was gathered. For example, neither Brendan nor Bianca were able to answer questions about what scientists did with data, even when probed in greater depth. Brendan, for instance, concluded that scientists use fossil measurement data to "study more about the fossil" without being able to explain how and why. Bianca stated that scientists "write [a conclusion] in their data" and "use their data to discover it when they find it." Neither of Bianca's comments have to do with using data to support an argument or derive a conclusion. Students' inability to comment on what scientists do with data most likely relates directly to their classroom learning experience, or to the lack thereof. Because students had not engaged in data analysis activities, they were not able to conceptualize how scientists worked with data. While these results may seem alarming, they are also indicative of the student learning in relation to engaging in scientific activities. On the positive side, students gained confidence in fossil identification and in the differences between making observations and inferences in data collection. In comparison to early classroom footage, these gains were made only through their participation in the fossil investigation.

Student responses within these interviews thus illustrate the impacts of engaging students in the activities of science within classroom environments. For example, students had more informed understandings about science activities that they had themselves experienced, such as data collection. However, understandings about the more abstract processes of science, such as how data is analyzed, remained beyond the scope of student understandings. From a broader perspective, student interview responses reiterated a possible divide between scientific ways of knowing and everyday ways of knowing. For example, students' thoughts about science and the work of scientists were shaped by their own surrounding lives and experiences. Therefore, unless these students had the opportunity to engage in scientific activities, their views on science may have remained uninformed. The complex nature of understandings about science and what scientists do also indicate that there may be social influences that shape students' understandings about science and there is a need for greater instruction toward making both NOS and the processes of science explicit for this particular student group.

*4. Students demonstrated growth in subject-matter knowledge about fossils and geology in class over the course of the instructional unit.*

Students in Monica's classroom completed pre-post measures related to Fossil Finders instruction. In this measure, the first 14 questions are multiple-choice and are oriented toward geology-based concepts (see Appendix F). The second portion of this measure consists of short-answer responses to VNOS-E questions, where students describe their views on science (Second part of Appendix F; Appendix G). Focus students' exams were reviewed individually by the researcher and scored using the answer key rubric for the multiple choice portion of the test. Student tests results indicated the most growth in the first four questions. For example, though only one of

the focus students answered Question Number 1 correctly on the pre-test, all five focus students entered the correct response on the post-test. These results indicate student growth in subject-matter understanding related to understanding the local environment of the past. All five students were also able to identify that the region was once covered by warm seas. Likewise, though only one of the focus students answered Question Number 2 correctly on the pre-test, all five focus students entered the correct response on the post-test. These results indicate student growth in connect-matter understanding related to understanding superposition, or the concept that older materials are deposited lower than newer materials. These five students were all able to identify where the oldest fossils were in a diagram of an outcrop cross-section.

Further, all students answered Question Number 3 correctly on the post-test measure, although there was only a 20% increase in the correct response. With these responses, students demonstrated understanding that fossils can be found in rocks in the ground. Last, most students (80%) responded correctly on the post-test for Question Number 4. This indicates a 40% increase in the appropriate response from the pre-test. These responses indicate student learning in the area of understanding the concept that, the remains of past living organisms buried in sand or mud may become fossilized. These first four questions demonstrate student subject-matter learning in relation to fossils. Students were not as successful in correctly responding to further questions on the test, which included content related to population characteristics and reading graphs. Of the focus students, Brandon demonstrated the greatest increase in learning. It is interesting to point out that although Raul demonstrated growth in conceptual understanding in class through informal conversation, this growth was not evident on his pre-post written measures.

Because not all students were able to demonstrate evidence of subject-matter knowledge on the pre-post measure, though they demonstrated subject-matter

understandings as a part of regular classroom interaction, the validity of this particular instrument with this group of students comes into question. Though the pre-post measure is a validated instrument, it also assumed English language proficiency. For this reason, further analysis on student learning focuses on student elicitations captured using video in class. Though these data will not provide information on individual student growth, they will supplement pre-post measure data with a general picture of student discussion in class. In particular, this analysis will focus its attention on Raul, one of the focus students who did not demonstrate significant learning on the pre-post measure. I choose to focus on Raul because of the trusting relationship we established during data collection. Raul would oftentimes call me (and the camera) over to share his thoughts about rocks and fossil samples. As such, I was able to gather a substantial amount of data related to his learning over the course of the instructional unit. Given his engagement in the unit and enthusiasm about fossils, his performance on the pre-post measure came as a surprise. For this reason, I chose to take a closer look at Raul's subject-matter understandings during classroom sessions.

This analysis will focus on video transcriptions of four instructional episodes involving Raul during different points of the unit. The first episode illustrates Raul as an inquisitive and imaginative learner, willing to share his inferences about the fossils he is looking at though his content-matter knowledge is limited. The second demonstrates Raul figuring out different type of fossils. The third episode portrays Raul's ownership of subject-matter knowledge and the degree to which he is able to identify various types of fossils, again with guidance from Monica. The last episode demonstrates the connections Raul makes between knowledge about fossils and greater geological concepts. Across these four episodes, Raul demonstrated growth in understanding that entailed first learning about what an "inference" is prior to making

an inference about the local environment during the Devonian time period, as well as mastering subject-matter related to identifying particular fossils.

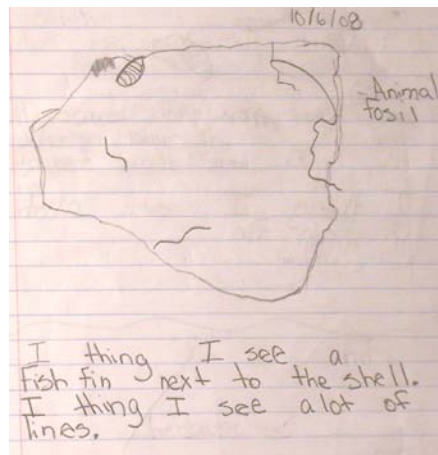
In the first episode, Monica provided a small group of students with a collection of fossils that she had gathered over the summer. These fossils were not the fossil samples that students reviewed as a part of the investigation and at this point in time, Monica had not yet instructed students about the particular fossils in her collection. Rather, Monica introduced her collection to students as an instructional tool related to what they would later be finding in the scientific samples of the investigation. When Monica distributed the rocks, she instructed students to make observations and then describe what organism they were seeing. Raul enthusiastically began sorting through the fossil collection making inferences about what he was seeing. However, he demonstrated little subject-matter knowledge about the fossils he was observing. For example, Raul described what he is seeing on the second day of making fossil observations (October 7<sup>th</sup>, 2008; Lines 43-46):

Raul:	I think I found a fish
Xenia	A fish? Why do you think it's a fish?
(Researcher):	
Raul	'Cause it has the fin right there and it looks like it has the eye
Xenia	Oh, it looks like a fish. The rock itself. Okay.
(Researcher):	

In this segment, Raul interpreted the entire rock as a fish fossil. He provided rationale for his thinking by pointing to striation formed on the rock, which he thought was a fin. Moreover, what he thought was an eye was an indentation in the rock. It was evident that Raul did not have enough subject-matter knowledge to help him distinguish which parts of an organism would most likely be fossilized, such as bones or outer skeletons, rather than soft tissue remains. Additionally, it was clear that Raul

lacked a basic conception of what kinds of organisms are contained in samples of rock from the particular time period the classroom was reviewing.

The following example further demonstrates Raul's thinking during this instructional day. Though the figure below is drawn from Paula's notebook, not Raul's, the two were collaborating while observing the same rock samples the previous day.



**Figure 4. Illustration from Paula's notebook; October 6<sup>th</sup>, 2008**

Here, Paula described also viewing a fish fin in her rock. She also described the rationale for her inference, "I see a lot of lines." It is evident that Paula and Raul co-constructed their rationale for why they considered that they were viewing to be a fish fin at the time.

In the second episode, Raul attempted to identify a fossil. This episode provided a snapshot of Raul's learning. When he shared his findings with Monica, she provided him with greater scaffolding about the process of identifying fossils and guidance related to specific features of fossils to look at in order to identify the fossil. With the guidance, Raul was able to correctly identify the particular sample. This

exchange is illustrated in the following transcription (November 24<sup>th</sup>, 2008; Lines 9-27):

- Raul: Hey Miss V, I think I found a tri-lo—bite  
Monica: Trilobite? Let's see. What do you think it is? Okay, a trilo... see, look at the trilobite and see if you see any difference between this and that?  
Raul: No  
Monica: You don't see any differences? How many sections does this have  
Raul: [Counting]  
Monica: Well, right here, go across, how many sections does it have? Right here, right here  
This is a section, this is a section, this is a section. It's three. This is split by like kind of like a backbone here or something like that. So, do we see that thing?  
Raul: No  
Monica: Do we see three sections?  
Raul: No  
Monica: Okay, and if this was the middle of the trilobite. Look at...  
Raul: It would be like curved...  
Monica: Right!  
So, now what does that look closer to?  
Raul: Segmented stems...  
Monica: Segmented stems...what are they called?... [pause] Crinoids!  
Well, that's good you found the right one. What do you think that might be?  
[Raul points to identification chart]  
Monica: Very interesting! Good job Raul! But, see, you have to look at details of the fossil.

Here, Raul made an interpretation that was incorrect. Monica guided him to have a closer look at what he was viewing in comparison to the fossil identification charts by pointing out the features of a trilobite and asking Raul to compare his sample to them. Raul was able to correctly identify the sample with this scaffolding, however, he was not able to name the organism. Again, Monica provided guidance in naming



the organism he was viewing. Monica provided positive feedback for the next sample that Raul identified and a take away message to consider the smaller features of the organism. It was not possible to discern which organism type Raul identified based on the video data; however, based on Monica's comments, Raul was able to do so correctly.

In the third episode, Raul was again interacting with Monica about a particular fossil sample he was viewing. In this clip, Raul turned to Monica with a rock sample he found interesting and Monica picked up a magnifying lens to view it more closely. Monica commented on the fact the fossils were in a cluster-like formation and asked Raul to identify what he may be seeing. Raul, in turn, identified what the fossils may be and provided rationale for his response. The following transcript excerpt illustrates this dialogue (December 1<sup>st</sup>, 2008; Raul; Lines 35-39):

- Monica: It's a cluster... it looks like a bunch of them living together. But I don't know...
- Raul: What about a brachio...
- Monica: Oh look, if you look here, what do you think they may be? Look at these little things and then maybe you can make an inference about what those are
- Raul: Oh...! [Monica stapling papers next to Raul] it looks like a little baby brachiopod by how it's shaped.

Here, Raul demonstrated a shared authority with his teacher, where he identified the fossil sample. Raul was self-assured with his tone and body language and demonstrated capability in differentiating between the different possible fossilized organisms that could be included in the rock samples that students were reviewing.



**Figure 5. Illustration from Raul's notebook; December 1<sup>st</sup>, 2008.**

The above figure illustrates a page of Raul's notebook, where he depicted the brachiopod colony that he identified. This, in contrast to the first episode, shows the extent to which Raul was able to make sense of what he was viewing and participated in the data collection parts of the project.

In the last episode, Monica was building on what the visiting scientist had talked about in her classroom. Up until this point, students considered the fossilized local organisms they had been reviewing as tropical sea creatures. However, students had not yet verbally made the connection that this meant that the local environment must have been covered by a tropical sea at one point in time. Monica restructured the scientists' comments in this transcription excerpt (December 9<sup>th</sup>, 2008; Lines 253-257) and in this conversational exchange, and she provided Raul with an opportunity to demonstrate deeper subject-matter understanding:

Monica: Okay, so she was saying that New York State at one time was like a Caribbean Island. So now we have these huge mountains and now if Miss S chopped from that mountain and found a clam, right, or brachiopod, what can we say about that mountain? New York State was high... no, New York State has all these mountains now and up in these mountains we are chopping these and knocking them down and getting these. What do we know? Raul?

Raul: It was underwater

Monica: It had to be what?  
Raul: Underwater  
Monica: Underwater! All of that was under water at one time! Excellent!

In this exchange, Raul made an inference about the past environment, building on prior learning about making inferences in science. Moreover, he connected understanding that the fossils were local and that they were also from a tropical environment to make the statement that the area had at one point in time been underwater. This is only possible to understand given knowledge about the organisms that had been fossilized, as the present-day local environment looks very different. By making this statement, Raul demonstrated deep subject-matter understanding and learning over the course of the unit between the various episodes.

Raul's case may be illustrative of the cases of other students in the classroom. Though Raul indicated learning to differentiate fossils and geological concepts related to fossil formation through classroom instruction, the pre-post evaluation did not illustrate this growth. The discrepancy in his performance on this measure may be indicative of language barriers or that the pre-post measure was not oriented closely enough to the materials that students covered during the instructional unit. As a result, it can be assumed that students learned more than the assessment measures were able to demonstrate. Data related to Raul also makes the case for the need to review more video data related to other students' learning.

### ***Emergent Findings Combining the Classroom Context and Student Experiences***

The findings presented above aligned with research questions and considered the classroom context and students learning experiences separately. The emergent findings listed in the table below stem from analyses grounded in video data, fieldnotes, and interviews with students. These findings present greater consideration for how the instructional approach employed by the teacher in her classroom, and

other learning opportunities, may have impacted student engagement in learning, student views on science, and student authority.

There was evidence of students' engagement stemming from a combination of the teacher's use of an instructional strategy and the students' experiences in the classroom, as displayed in Table 18. The findings presented in the analyses above

**Table 18. Emergent Findings Combining the Classroom Context and Student Experiences**

	<i>Emergent Theme</i>	<i>Findings</i>
1	Student engagement in learning was affected by the type of instructional approach used by the teacher	Students demonstrated greater amounts of engagement and motivation to learn when interacting with fossils in small group-work settings than during large-group instruction.
2	The interaction of students and a scientist in the space of school created important opportunities for students to reconsider their views on science.	When a scientist visited the class, this impacted focus students' views on science and enhanced their interests in pursuing scientific careers.
3	Student authority was influenced by the structural constraints of the classroom as related to other school program.	When students with lower levels of ELP were drawn from class, the classroom community was impacted. For example, it fostered greater amounts of confidence in science for students with higher ELP levels.

consider how the instructional approach was implemented in the classroom. This analysis focuses on how students responded to the instructional strategies used by their teacher and is grounded in video data analysis. Student behavior in these videos was used as a guide to evaluate student engagement in learning.

Next, a classroom visit by a scientist provided important learning opportunities for the students. The visit was not anticipated in the original research design of this investigation. However, the visit provided the researcher a unique opportunity to observe how students interacted with a scientist within the context of an authentic investigation. Students were able to voice questions related to science as a field and

what it may take to become a scientist in an informal setting. In this way, these data provide interesting glimpses into the interactions between a scientist and students in the space of school around an authentic investigation, which merges with previous considerations of overlapping communities of practice. As a result of this event, students demonstrated changes in their views about science and interest in pursuing scientific careers.

Differential authority in the classroom based on ELP became an emergent theme based on observations of the structural implementation of the curriculum and other school programs. Further, the sharing of scientific authority is an important feature of IC. Thus, the distribution of student authority in the classroom was considered. Because certain students were drawn out of the classroom for specialized language instruction during science lessons, they had less time to engage in learning about science. This, compounded by ELP levels, may have adversely affected their participation in class.

### *Supporting Data and Analysis*

The following section supports emergent findings in relation to classroom context and student learning experiences with data.

*1. Students demonstrated greater amounts of engagement and motivation to learn when interacting with fossils in small group-work settings than during large-group instruction.*

Both student behavior and interviews indicate greater student engagement in science while interacting with fossils within smaller group-work settings than during large group instruction. A comparison of student responses between early episodes of instruction, where Monica used a direct-instruction approach to introduce the unit and

an activity, and later classroom discussions among students provides evidence for change in student participation and involvement. For example, Monica initiated the Fossil Finders unit using large-group instruction (Day 1 and Day 2). Students sat in two long rows of face-to-face desks and turned toward the front board of the classroom. There, Monica used an overhead projector to project and lead students through the three stages of the Tricky Tracks activity (Figure 2). In this activity, Monica uncovered each segment of the Tricky Tracks image on the overhead and asked students to write notes about what they were seeing. Monica then asked students to share their notes with the rest of the class at the end of each stage. Certain students consistently volunteered to read their notes from their pages; however, the students did not discuss observations further. Monica facilitated interaction between students in a structured format following student responses. This can be illustrated in the following transcript segment, where Niko read what he thought was occurring during the Tricky Tracks scenario to the rest of the class (September 30<sup>th</sup>, 2008; Lines 186-189):

- Niko        I think that one day two dinosaurs were trying to catch an animal. And one of them caught one and the other dinosaur started to bite the dinosaur. And he killed it. And one of them walked off and left the second one didn't die. It went home.
- Monica:    The other one didn't die, it went home?  
Anybody agree? Who had the same type? You have question or a comment for Niko? Bianca?  
Do you have a question, or comment, no? Oh, cause, your hand was up.

It is evident that Monica maintained control of the classroom by first commenting on one student's presentation of ideas, and then inviting other students to also respond. In this way, she directed the flow of conversation. Moreover, Monica called on particular students to comment, though few students indicated willingness to respond to their classmates' ideas. Though Monica made an attempt to engage students in

verbal discussions in the example above, her approach remained teacher-directed, rather than student-centered.

Monica also attempted to integrate collective sense-making as a part of instruction. This, however, was also tightly structured, more along the lines of orchestrating a classroom discussion. This form of instructional exchange is illustrated in the following transcript excerpt, an earlier segment of the Tricky Tracks instructional lesson where students were first commenting on what they thought they saw (September 30th, 2008, Lines 74-92):

- Monica: Okay, what types of animals you thought it was, Renee?
- Renee: A duckling and bird.
- Monica: Okay, you thought one was a duckling and one was a bird. What did you think, Carolina?
- Carolina: A frog and a bird.
- Monica: A frog and a bird. What did you think, Bianca?
- Bianca: A raccoon and duck.
- Monica: A raccoon and duck. What made you think they were two different types of species? Why did you think there were two different types of species?
- Niko: [*without being called on*] Because they have two different types of footsteps.
- Monica: Okay, what makes you think that there were two different types of footsteps? [*student: an enthusiastic "ooh!"*] What did you observe, Jorge?
- Jorge: Because one footprint is big and one is little.
- Monica: So, you're making an inference that there has to be a big animal and a small animal. How many animals do we think are involved?
- Eva: Two?
- Monica: Okay, thanks. Eva, you think it's two. What makes us think it's two? What are we observing that makes us think it's only two animals? What can you observe that makes it two animals. [*some students sketching, about six eagerly raising hands to answer question, others do not appear interested*] Alyssa.
- Alyssa: That they're different.

- Monica: Okay, we got that. So, we're thinking that one species is bigger than the other and we're thinking that there're actually two different species. Isabel?
- Isabel: Because there's two types of footprints that look the same. Well, one pair of footprints look the same and the other look the same.
- Monica: Okay, two sets of footprints and they look a little different. But, what makes us think that there's only two animals involved? Who can put that in their own words? How can we tell that there's only two animals involved? What makes us think that? Matias?
- Matias: Because there's only two pairs of footprints.
- Monica: Only two pairs of footprints! And, we know from our own past experiences, if you've ever walked in the snow that hasn't been touched? So, you only see one set of footprints. Right? So, we know from past experiences that it's possibly just one animal because there's not a bunch of footprints together. Right? Is that how you're making that inference?

Though Monica was facilitating a structured discussion, her conversational turns illustrated that she, rather than the students, was making the subject-matter connections. While some students seemed engaged in participating in the discussion, others did not verbally contribute. It is difficult to assess the extent of student participation in this segment, as students may have been actively listening but did not show it. However, body language indicates that this perhaps may have not been the case. Certain students did not seem to be engaged in the facilitated discussion based on the fact that they were working on other things (sketching) and had their heads down. These students remained passively involved in learning. In further instructional segments, Monica gave students instructional turns to share what they were finding with their neighbors, which created more active learning opportunities. However, video transcriptions indicate that Monica continued to maintain control as the leading discussant in this large-group instructional setting, as evidenced from analysis of video transcription.



During Day 3 of instruction, students began to work in smaller groups. This small group work illustrated another type of classroom organization. Students engaged in greater amounts of student-top-student and student-to-teacher interaction, collaboration and collective group sense-making. As students shared ideas about what kinds of fossilized organisms they thought they were seeing with one another and collectively discussed their ideas, they demonstrated greater ownership in their thinking and authority. Students also made use of their native languages, or making use of Spanish, while talking about fossils. In the following segment, the researcher engaged with student groups to ask about what they had been working on and what they were finding in their rock samples. The following segment is illustrative how the shift in instructional setting repositioned students as active learners with authority in the classroom, which in turn may engage them in science subject-matter learning (October 7<sup>th</sup>, 2008; Lines 84-105):

Xenia (Researcher):	[To Damian] Me puedes mostrar que tienes?	Translation: "Can you show me what you have?"
Damian:	A rock and in that rock I see a backbone and... more fossils	
Xenia (Researcher):	Okay. Where's the fossil? Can you show me? I'm going to zoom in. Oh yeah, there's something there.	<i>[Damian points to rock with pencil]</i>
Eva:	And the backbone, the backbone, right here	<i>[Damian points to rock with pencil again]</i>
Brendan:	And we see like this thing... there's a shell right here	<i>[Interjects from the other side of the table; points to rock with pencil]</i>
Xenia (Researcher):	Okay. Something there too? What do you think that is?	
Brendan:	Like a clam shell?	
Xenia (Researcher):	Okay. Do you agree?	<i>[to Matias]</i>
Matias:	Yeah!	
Xenia (Researcher):	Okay... What else did you find?	

Damian:	Se ve como...	<i>[From across the table];</i> Translation: "It looks like"
Matias:	Seashells	
Brendan:	Yeah!	
Damian:	...Piel de un dinosaurio. Aqui, aqui!	<i>[From across the table];</i> Translation: "Dinosaur skin. Here, here!"

The researcher engaged in discussion with the students, who in turn shared their current thinking about the fossils they were seeing. It is evident that students were enthusiastic about the content matter and working in groups. For example, while the researcher was talking to one group of two students, Brendan jumped in to talk about what he and Matias were observing in their rock samples. While the researcher talked with the second group of students, Damian continued to talk about what he was viewing to Eva. The collaborative approach facilitated greater meaning-making between students and illustrated an active approach to engaging with subject-matter. As students continued to collaborate in their small groups and built subject-matter knowledge, they also engaged in animated discussions about what they were seeing. For example, Matias and Isabel were enthusiastic and competitive about finding a trilobite follow in the following episode during Day 12 (December 12<sup>th</sup>, Lines 371-374):

Matias:	Hey look, I found a trilobite!
	[Isabel grabs another rock from the pile]
Isabel:	I found a trilobite!
Matias:	Let me see!

These students were notably engaged in the classroom activity and self-motivated to continue learning more about fossils. Follow-up interviews with focus students also indicated more interest in learning science, once students began to engage in working with actual fossils. As described above, Alyssa shared that before the class started

working on fossils, she thought that doing science was reading out of a book. Raul shared that he kept getting more and more interested in fossils as the class became further involved with the instructional unit. These perspectives corresponded with Monica's shifting practice from teacher-directed instruction, in the beginning of the unit, to more student-centered instruction that allowed students to investigate actual fossil samples.

*2. The introduction of a scientist impacted the students' views on science and interests in pursuing scientific careers.*

The introduction of the scientist, Trina, impacted the classroom community. Trina came into the classroom in regular casual clothing (no white lab coat) and a friendly demeanor. Many students had never interacted with a scientist and they were able to ask Trina questions about science content and practice. Many of these questions focused on the process of becoming a scientist, rather than how scientists do their work. For example, in the transcription below Anamaria asked the scientist how long she needed to study to become a paleontologist (December 10<sup>th</sup>, 2008, Lines 30-34):

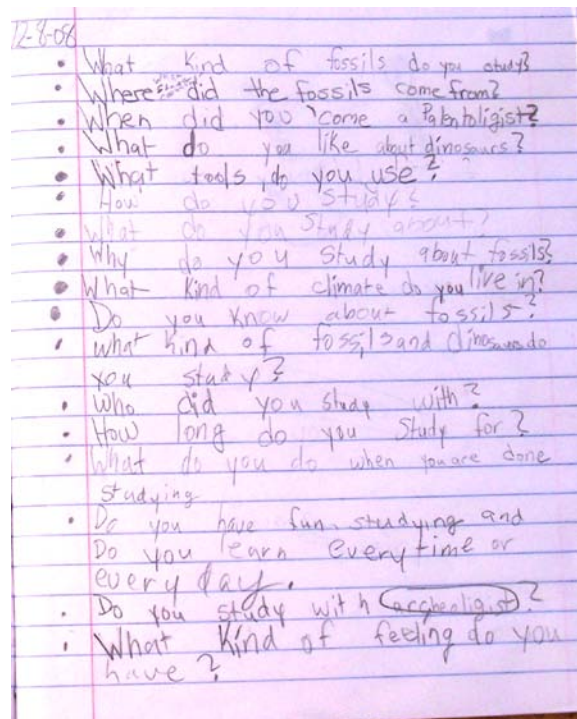
Anamaria: How long have you studied to become a paleontologist?

Scientist (Trina): High school, did the math stuff, the science stuff that everyone else did, paid attention, did 4 years at a college. I had to go to school for another 2 years, but I did a bunch of other stuff so it wasn't all science all the time.

Students asked the visiting scientist a number of other questions along the lines of how does one become a scientist. Figure 6 illustrates a list of questions that a focus student, Paula, prepared to ask the visiting scientist. These questions demonstrated

that Paula was interested in learning how the paleontologist conducts science: what tools do you use, how do you study, and how long do you study for? Though these questions uncover the processes of entering the scientific community of practice and being within it, rather than NOS, they also serve to deconstruct the structural constraints of science. Students for example, may or may not be certain about the amount of time it takes to conduct research.

Focus students reflected an increased interest in science and pursuing careers in science following the Fossil Finders instructional unit and scientists' visit. For example, Alyssa, whose family had recently immigrated to the United States from Puerto Rico, shared that she had always wanted to meet a scientist. She wanted to learn what scientists did and how they felt (Alyssa Interview, December 15<sup>th</sup>, 2008). As stated above, this and other students' views about science and scientific research changed after participating in activities related to the Fossil Finders investigation.



**Figure 6. Questions for Scientist from Paula's Notebook; December 8<sup>th</sup>, 2008**

Interestingly, though students demonstrated more sophisticated understandings of science after engaging in the curriculum and interacting with a scientist, many ultimately deferred scientific authority to expertise of the scientist. For example, in days following the scientists' visit, I asked Alyssa how she determined what a particular fossil was. She responded, "Because the scientist said so" (December 12th, 2008, Line 614). Though one of the core purposes of engaging students in the authentic work of scientists and inquiry was to bolster the scientific authority of students, these students' comments pointed to structural components of the curriculum allowing students to continue deferring authority to scientists. For example, the teacher explained that she had learned a lot by working with scientists (September 30<sup>th</sup>, 2008; Tape MV1). Students also viewed the Fossil Finder's program website (December 8th, 2008; Tape MV16), which contains an "Ask a Scientist" section devoted to relaying questions from the classroom to practicing scientists. Though this site structurally provided a way to better connect classroom and scientific communities, it may have also served to reinforce the false presumption that scientists may in fact have all the answers.

*3. When the teacher used specialized language instruction for students with lower English language proficiency (LEP), this had an impact on the classroom community and fostered greater amounts of confidence in science for students with higher ELP levels.*

The classroom composition and school-based protocols had an impact on the classroom community. The twelve students with lower levels of English language proficiency (ELP) were drawn out of science classes for specialized instruction. This

group was sub-divided into two sections with differing needs. Students with moderate language development needs received specialized instruction for 15-minute blocks of time, while students with greater language development needs received instruction for 30-minute blocks. Monica would initiate Fossil Finders activities with the group of eight students having the highest levels of ELP, who remained in class. These students were designated as the “Fossil Finders Leaders.” These leaders were distributed in pairs, amongst four groups of four to five students from the rest of the class. The Fossil Finders Leaders were assigned to re-teach Monica’s earlier instruction and help the English language learning peers in their small group.

Video data provided evidence of the frequency each student presented in front of the class. Students with stronger levels of ELP volunteered to share their work with the rest of the class more often than students with developing levels. These students, in turn, received more immediate feedback from their teacher and peers. These data indicate that these particular students may have had greater opportunities to interact with their teacher and also develop scientific authority, as demonstrated by their confidence to share their thoughts with the rest of the class. Consequently, of the five focus students that I interviewed, I selected two from groups with developing English-language skills to obtain a better representation of other students’ views of science. This was difficult decision to make, as I struggled with the notion of removing these students from the limited instructional time they had for science learning.

### ***Emergent Findings Related to Everyday and Cultural Experiences***

The emergent findings listed in the table below stem from analyses grounded in video data, fieldnotes, and interviews with students’ family members and consider spaces of cultural exchange and how students’ understandings of science may be shaped outside of school. Primarily, emergent findings focus on how the teacher

employed familiar classroom instruction and literacy strategies to create a space for cultural exchange in relation to science. Other findings consider family views on everyday ways of knowing, science, and science learning and teaching in schools, which may shape student views and understandings about science.

This table describes the various emergent findings from data collection and analysis. A primary observation stemming beyond the original research questions was Monica's use of story-telling and story-writing. In this space, she was able to merge science instruction with her use of story-narration and student literacy-skills development. Story-telling and writing thus became a space for combining science,

**Table 19. Emergent Findings Related to Everyday and Cultural Experiences**

	<b>Emergent Finding</b>	<b>Support</b>
1	Story-telling is a place of cultural exchange for science, everyday ways of knowing, and the imaginary	Students bridged between everyday understandings, science, and the imaginary through story-telling and story writing. The scientist used a story-telling approach when visiting and thus contributed to this genre of science learning.
2	Parents have culturally influenced views on science	Parents' indicated varied views and skepticism about science
3	Parents view importance of science instruction for their children	Parents expressed wanting their children to experience active instruction that would engage them in learning science.

everyday ways of knowing, the imaginary and a space for cultural exchange between the three. Parents' views on cultural ways of knowing and views on science and science instruction were determined from analyzing the interviews with parents in their home settings. Parents, for the most part, did not recognize the wealth of cultural learning occurring in their home settings (See Appendix K); however, they viewed certain aspects of science as particular to scientific ways of knowing. Moreover, they

presented varied views about the utility of science and skepticism about scientific ways of knowing in relation to other ways of knowing. Nonetheless, these parents wanted their children to have stimulating classroom experiences that would engage them in science learning.

### *Supporting Data and Analysis*

These emergent findings are presented below with supporting data and addressed in relation to other findings and theory in the discussion section.

*1. Students bridged between everyday understandings, science, and the imaginary through story-telling and story writing. The scientist used a story-telling approach when visiting and thus contributed to this genre of science learning.*

The classroom context of story-telling and story-writing created a space for students to merge imaginary, home, and scientific understandings. In this way, Monica's use of literacy activities and assignments shaped students' science learning experiences in her classroom and bridged between scientific and everyday understandings. Within this space, students were able to use home and everyday language, with structured support and editing from their teacher, to further their understandings, both imaginary and realistic, about science. Nonetheless, students largely did not recognize story-writing and telling as a formal space of learning. This is why the following supporting data is particularly interesting to consider.

Monica included story-reading as a regular part of classroom instruction. As described in the classroom context section of results, Monica would find various fiction and non-fiction texts to share with students. In early parts of instruction, she flipped through images of dinosaurs as the class discussed what environment they lived in. In latter parts of instruction, Monica read a story out loud about a young boy



on a fossil dig. She then asked students to make predictions related to what would happen next, as an integral part of her reading. The scientist's visit to the classroom was also structured as a story-telling session, mostly directed by individual student questions. The context of story-telling thus played a large role in shaping the delivery of instructional content in this particular classroom.

The use of the word "story" and "text" were embedded within Monica's instructional approaches in various ways. For example, when Monica introduced students to the subjective aspects of science, or the concept that scientists may have different ideas about what they are viewing, she referred to their *theories* as stories. The following transcript excerpt illustrates how Monica makes this comparison (October 6<sup>th</sup>, 2008; Line 376):

Monica: If [scientists] all have the same facts, why do they have different theories, remember we said it was different stories? This is the perfect example of how we can have the Tricky Tracks, the same facts, the same observation, but yet we are making different inferences, right? Different takes on what could have been. Does that make sense to you?

As mentioned earlier, though this is perhaps not the appropriate scientific meaning of the term theory, nor is there a clear link between various opinions of scientists and stories, Monica's use of the term *stories* may perhaps have made science most accessible to students at that particular moment in time. Monica also made use of literacy strategies to point out possible connections between texts in her classroom. These possible connections included: text-to-text, text-to-self, or text-to-world. As part of instruction, Monica questioned students about new text they were coming across and ways in which they would make connections. For example, fieldnotes indicate that on December 2<sup>nd</sup>, 2008, Renee came back from the library with a book and was enthusiastic about having found a photograph of a brachiopod in it. In response, Monica asked what kind of connection she would make. Renee responded

that the connection would be “text-to-world.” In another instance, Monica read from a book and asked students to consider the connections between text (December 10<sup>th</sup>, 2008; Lines 158-163):

- Monica: Who do we know that's on the hunt for a big fossil? Who do we know? [Hands go up] What is the name of the text?  
I know Brendan knows. And, the man is on the hunt for a man eating fossil.
- Brendan: The book is called "Fossil Fever"
- Monica: “Fossil Fever!” So this would be a text-to-text, right? You can make a text to text connection? [Shows image]

Monica’s framing of texts encouraged students to think across ways of knowing and how texts could relate to each other, to students, and to the world outside of school. This instructional approach implicitly considered understandings about science and science subject-matter. In this space, students mediated learning, or what was in the text, with their other understandings. For example, students would not be able to make a link that was “text-to-world” without considering what constituted the world, or the world from their perspectives. It would be interesting to consider an instructional approach that would include explicit questioning related to links between classroom science, the self, and the outside world.

Additional embedded literacy strategies included story writing. As an integral part of learning about NOS, students composed “Tricky Tracks” stories. In these stories, they described what might have occurred in the footprint scenarios of the NAS activity, “Proposing Explanations for Fossil Footprints,” as described above. Students were instructed to “use their imaginations” to consider the environment the organisms lived in, in order to leave behind tracks, and propose what scenario may have occurred.

A long time ago, on a rainy, hot, humid evening during a thunder storm one could see a sunset forest covered with purple, red, and pink roses. One day a Pterodactyl and a Stegosaurus were walking. Pterodactyl found some food and was munching on it. Stegosaurus went looking for food and found Pterodactyl. Pterodactyl said, "Hi my name is Friendly." The Stegosaurus said, "My name is Big!" The Stegosaurus was bigger than an Iceberg! After that the Pterodactyl said, "Why are you so big?" The Stegosaurus said, "I don't know I'm just a toddler."

**Figure 7. Excerpt from Paula's Story "Dinosaurs"**

Students were also reminded to tie their stories back to the tracks, or to make use of evidence when writing their stories. While writing their stories, students began to question how to make use of science, with respect to subjectivity and imagination. Though through instruction, students gained an understanding that they could have different takes on what happened within the scenario, much like scientists have their own "stories," they were uncertain whether these stories could be fictional. On the one hand, the tracks were identified as made by a dinosaur. On the other hand, Monica commented on anthropomorphic activities that students suggested that the dinosaurs were doing, such as "going home," when they were not supported with actual evidence in the tracks. Monica encouraged students to make use of actual

dinosaur names; however, opened the space for students to create their own scenarios. These scenarios varied across students, including dinosaurs playing musical chairs, going to jail, and fighting for food.

In the story above, Paula described how two dinosaurs, a pterodactyl and a stegosaurus, meet and become friends after fighting for food. Paula also described the surrounding setting, with a thunderstorm, and an erupting volcano. Though she never made connections between rain, mud, and tracks, or the volcano and whether fossilization of the dinosaurs' tracks could occur, Paula exhibited use of imagination combined with science through writing the story. Other student examples also demonstrated students integrating their everyday understandings of life and some understandings about science with fictitious understandings of the activities of dinosaurs within the space of story-writing. While the Tricky Tracks story writing activity was framed as a way to consider the subjective notions of science, it is uncertain whether the Monica intended having students merge these other understandings and views.

Another example of a classroom story-writing activity is focused on students describing how rocks tell stories. Rather than listening to or narrating stories in their own voice, students framed rocks as actors and explained how their features can describe the geologic past. This story writing activity was not an original component of the Fossil Finders curriculum; however, it utilized components of the professional development session Monica was involved in and subject-matter students learned during the instructional unit. Moreover, in contrast to the Tricky Tracks stories, these stories made greater use of students' understandings about science. In Figure 8 below, Paula described how rocks tell stories.

**Rocks Tell Stories**

Did you know that rocks tell stories?

I learned that rocks tell stories, because I am a Fossil Finder. I found some clams, trilobites, brachiopods, ammoniod, gastropods, rugose coral, crinoids, and segments of stems in the Sedimentary shale. I learned that my teacher found these fossils in Ithaca, New York. Thes fossils are of life forms that lived in a tropical climate. I can infer that New York State was once underwater. If I lived in a tropical climate, I would go to the beach and look for shells and clams.

**Figure 8. Paula's *Rocks Tell Stories* Final Draft; May 6<sup>th</sup>, 2009**

In this short story, Paula identified herself as a “Fossil Finder” and listed the fossils that she had come across, which included clams and shelled organisms. In addition, she described where these fossils were found and what this meant in terms of the environment of the past. “Thes fossils are of life forms that lived in a tropical climate, I can infer that New York State was once underwater” [sic]. Paula demonstrated geological subject-matter learning about the past and the ability to relate this to everyday life today. She wrote, “If I lived in a tropical climate, I would go to the beach and look for shells and clams.” It is interesting to note that many students in this particular classroom pay frequent visits to tropical areas in the Caribbean, creating a personal link to this subject-matter. Other students also included similar discussions of subject-matter, including reasons why one should consider observing rocks.

Brandon

When you examine a rock  
you will notice lines and possibly indentify  
a fossil, which will tell you a story about  
earth. Many people think that rocks are  
boring, but they're not. Don't waste a good  
rock story by skipping in the water. ROCKS

**Figure 9. Brandon's *Rocks Tell Stories* Final Draft; May 6<sup>th</sup>, 2009**

demonstrated both knowledge about and interest in the subject-matter. This indicates that since completing the investigation in December, content was both retained and relevant nearly five months later.

Monica's use of embedded literacy strategies served as a pathway to learning science. While the classroom engaged in the practices of reading and writing, both scientific and everyday understandings were brought into the space and promoted cultural exchange. This was evident through students' identification of linkages between texts, or connections between science content and the self or the outside world and their use of imagination in considering the environment of the past. Moreover, student story writing also provided evidence of student content-matter knowledge. It is evident that the instructional approach used by Monica created a platform for cultural exchange between the imaginary, scientific, and personal spaces of students. Additionally, examples of student writing provided another format for demonstrating understandings, which may or may not have been captured through classroom interaction or formal assessments.

## *2. Parents' indicated varied views and skepticism about science*

In interviews with students' parents, I asked questions about their views on science and whether scientists' findings were always right (see Appendix J). Parents responded in a variety of ways, mostly framing science as a certain way of doing things and indicating skepticism about its validity. Alyssa's mother, for example, used medicine as an example to explain how science and the work of scientists may vary. "Medicine has different ways of doing things." In framing medicine as an entity and likening science to it, Alyssa's mother acknowledged science as a particular way of knowing that is diverse in and of itself. Paula's mother defined science by the practices and attributes required to do scientific work. She stated, "Science is all about experiments, patience, and concentration." For Paula's mother, science had a purpose and could "answer questions about nature; the hemisphere." However, also using medicine as an example, Paula's mother stated "Not all people trust scientists." She also commented that at times, science can come into conflict with other cultural views, such as religion. Raul's mother also defined science by its practices, stating "science is all about inventing, figuring things out." In describing how she approached problem solving herself, she responded "I try all kinds of things to work [problems] out." Hence, she commented on a variety of possible approaches that could be used to solve questions; much like science. Nonetheless, Raul's mother also expressed doubt in science as a foolproof method of finding solutions to problems when she stated "science sometimes works." Bianca's mother defined the purpose of science as "the study of the world." She too, claimed to try to figure things out by asking questions, asking for advice, looking things up, and using her intuition. According to Bianca's mother; however, science is "bicultural." In this way, Bianca's

mother commented on her viewpoint of science being able to cross cultural boundaries.

These interview comments are evidence that these parents held a range of views on science, from perspectives that science may challenge traditional and religious viewpoints, to science as a way of knowing that has the potential to crosses cultural differences. Many parents considered the purposes and practices of science in their responses as well. Interestingly, almost all interviewed parents indicated some sense of doubt in the authority of science, however. It can be inferred that the expressed viewpoints may have some role in shaping students' views about science.

*3. Parents expressed a desire for their children to experience active instruction that engaged them in learning science.*

The five parents interviewed indicated they had confidence in the school their children attended and in Monica's classroom. They were also excited to have their children participate in an authentic scientific investigation in the context of their classroom. Though none of the parents worked in science-oriented fields, they shared views that engaging students in the activities of science would supplement their learning experiences. Paula's mother felt that it was important to "educate children in a dynamic way so that they're interested more." This included "tak[ing] them to interesting places" as part of schooling. Raul's mother for example, thought "education is more hands-on" than it tends to play out in schools. She stated that she can explain things to her son at home, while what he needs at school is "more hands-on, and do-it-yourself learning opportunities." Raul's father also shared many of her viewpoints. He felt that traditionally in schools, today, "the teacher says this is how it's supposed to be then this is what it's supposed to be." However, it is important to



provide students opportunities to engage in learning. This is because “all kids are interested in science, touch[ing] metal, [having] more projects.” As a result of such learning opportunities, he felt that the “brain develops most” and leads to students “having questions to get those answers.” Raul’s father considered the influences that school science learning may have on students’ perceptions of science. “Schools get it into their minds of what science is all about.” This knowledge tends to misrepresent actual science, he added.

Across these parents’ responses, it is evident that parents felt that learning opportunities that engage students in active learning are both beneficial to maintaining students’ interest in science and to their development as learners. These parents viewed the authentic and experiential learning opportunities, such as having class visits and hands-on opportunities, as useful to this end. It is interesting to note that though these parents had a variety of views about science, including skepticism, they were still supportive of providing learning opportunities for their children to excel in this subject area.

### ***Summary***

This chapter presented findings in relation to the research questions driving this investigation and emergent findings stemming from data collection and analysis. The first segment of this chapter described the implementation of the Fossil Finder’s curriculum. Findings related to the classroom context and the nature of instruction established the instructional setting through which science content-matter was presented and the extent to which inquiry, IC, and explicit instruction in NOS played a role. Results presented above suggested the ways in which Monica included the features of the focus constructs into her teaching.

The second portion of this chapter addressed students' experiences in Monica's classroom in light of her instructional approach. Findings related to student experiences in the classroom considered how students engaged in inquiry and how the combined instructional approach may have supported science learning and negotiating between science and their everyday lives. This included a discussion on how students engaged in features of inquiry, how they connected science learning to their everyday understandings, and how they developed understandings about NOS through the context of the investigation. Data with respect to these findings also demonstrate student growth in content-area learning, understandings about science, and interest in science. These two sections purposefully separated Monica's instructional approach from her students' experiences.

The third section of this chapter addressed other themes emerging from the data beyond the scope of the original research question and took findings with respect to combining the classroom context and student experiences into account. Other emergent findings stemming from observations beyond the scope of the original research questions both bolster the theoretical considerations of this research and present alternative conceptions of what may have occurred in the classroom setting. Findings related to combining the classroom context and student experiences consider the impact of instructional practices on student perceptions of science. This included student engagement in learning through the context of an inquiry-based investigation, interaction with a scientist as an invitation into the scientific community of practice, and scientific authority in the classroom with respect to varying levels of ELP.

Findings related to everyday and cultural experiences in this section considered spaces of cultural influence and exchange. This includes Monica's use of storytelling in the classroom and its role as a space for cultural exchange between science, everyday ways of knowing, and the imaginary. Further, this section presented

findings with respect to the focus students' family members' perceptions on cultural knowledge and science, which may have partially served to shape student perspectives. This particular segment of emergent findings presented the complexities of negotiating cultural ways of knowing with science and the great potential for science learning in a classroom context with authentic learning experiences and platforms supporting cultural exchange. The Discussion section will next focus on synthesizing these findings into themes in relation to the theory and research questions driving this investigation.

## **CHAPTER 5**

### **DISCUSSION**

Science education reforms form a point of departure from traditional classroom instruction in science in that they seek to engage students in the activities of science (NRC, 1996; 2000; Rutherford & Alghren, 1990). Traditional classroom instruction has proven unsuccessful in reaching student groups who remain underrepresented in the sciences. Alternative reform-based instructional approaches, such as inquiry, thus provide promise. Engaging students in an inquiry-based instructional approach largely finds theoretical support within science education literature, from the perspective of bringing students into scientific communities, contexts, and practices. Other theoretical perspectives, however, consider the role of transmitting scientific culture by enculturating students into science (Jegede & Aikenhead, 1999). Drawing from sociocultural theory (Holland et al., 1998; Lee, 2002) and applying a sociocultural lens to science (Lemke, 2001), participation in inquiry and negotiation of scientific understandings may be problematic to students from diverse cultural backgrounds and the very backgrounds that are underrepresented in the sciences.

Research is needed to understand how underrepresented students may be supported in science learning and negotiating understandings about science. The current study considers combining inquiry with IC teaching to increase the accessibility of science content and to bring everyday and cultural understandings into the science learning process. This research forms a point of departure from other work by considering explicit instruction in NOS as an integral part of culturally relevant instruction; that of making the culture and assumptions of science explicit to students, rather than only experienced through inquiry. It also differs from other research on

inquiry with underrepresented and ELL students in that it investigates Latino students' participation in science through the context of an authentic investigation with scientists. To this end, this study focused on the utilization of an instructional approach that combined inquiry with IC practice and explicit instruction in NOS in a classroom serving underrepresented students through the context of the Fossil Finders project. This section summarizes, evaluates, and interprets results with respect to the overarching questions driving this research: 1) *How did the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach*, and 2) *How did underrepresented students experience and respond to an instructional approach combining inquiry, instructional congruency and explicit instruction in NOS?*

In this chapter, I will first summarize findings in relation to the research questions driving this investigation. This includes a discussion and interpretation of findings related to establishing the instructional approach used by the teacher, as well as findings related to student experiences. I will then seek to recombine student learning experiences with the instructional approach used by the teacher by drawing themes from findings related to research questions and emergent findings. These themes will be discussed in further detail and related to the theory guiding this research. Moreover, within each of these sections, I will address the theoretical and practical consequences of the results, validity of the conclusions, and limitations of the study. Finally, I will offer suggestions for future work.

### ***Discussion of the Teacher's Use of Inquiry, IC, and NOS***

Understanding the teacher's instructional approach in the context of the Fossil Finders unit was an important element of this study. Without a clear understanding of

how the teacher implemented the curriculum unit, it would not be possible to make inferences about what may contribute to student learning or their experiences. This

**Table 20. Instructional Approach by Focus Constructs**

	<b>Research Sub-Question</b>	<b>Associated Construct</b>	<b>Observations and Findings</b>
1	In what ways does the teacher engage students in inquiry?	The implementation of inquiry	Monica engaged students in all aspects of inquiry to some extent, though she did not complete the entire scope of the Fossil Finders curriculum; her instructional approach demonstrated evidence that the classroom community shifted from teacher-directed questioning, to a classroom environment exhibiting student-driven questioning and inquiry over the course of the instruction.
2	To what extent does the teacher use instructionally congruent strategies for teaching science?	IC in the classroom	Monica demonstrated regular use of instructionally congruent strategies in teaching science, which included extending regular science learning activities into literacy-focused assignments.
3	In what ways does the teacher make NOS explicit to students during instruction?	Explicit instruction in NOS	During instruction the teacher provided explicit instruction related to certain features of NOS; however, she did not address all features of NOS or consistently connect classroom activities to the authentic work of scientists.
4	How is the combined instructional approach implemented in a classroom and which features of the constructs of inquiry, IC, and explicit instruction in NOS come together in instruction during Tricky Tracks instruction?	Combined inquiry, NOS, and IC	Monica successfully merged IC practice with inquiry and explicit instruction in NOS through the context of the Fossil Finders project this combined instructional approach; most of the features of inquiry and NOS were addressed during instruction

section discusses findings related to the question: *How did the teacher make use of inquiry, instructional congruency and explicit instruction in NOS as an instructional approach?* Four sub-questions based on this question directed closer attention to features of instruction surrounding the theoretical premises of this research: inquiry, IC, and explicit instruction in NOS. Table 20 summarizes findings with respect to these sub-questions.

### *Use of Inquiry in the Classroom*

Research related to Monica's use of inquiry in the classroom addresses the various features of inquiry (NRC, 2000) in her instructional approach. Findings from video data indicate Monica engaged students in all five features of inquiry (Table 5) over the course of the instructional unit. Though students did not instantiate the full scope of the Fossil Finders investigation, they were nonetheless able to experience these features of inquiry (Table 8). Further, although she never used open-ended inquiry, Monica enacted an instructional approach that moved along a continuum from a teacher-directed to student-centered approach (NRC, 2000, p. 29). These findings align with literature on the possible variations of the instructional implementation of inquiry (Songer, Lee, & McDonald, 2003). Further, the inquiry-based instructional approach used in Monica's classroom aligned with the framework for instructional congruency proposed by Luykx and Lee (2007) and provided students with an opportunity to develop scientific authority and agency in the classroom. Though other research has been conducted on classrooms using inquiry-based instruction with underrepresented students (Lee, 2002; Lee et al., 2005; Lee et al., 2006; Warren et al., 2001), these studies do not describe what aspects of inquiry students were involved. The relevancy of these findings with respect to the literature on science and multicultural education is discussed in further detail below.

The Fossil Finders curriculum provided students in Monica's classroom with opportunities to engage in all the features of inquiry over the course of the instructional unit. For example, while observing fossil samples, students asked scientifically oriented questions about them and connected age-level appropriate scientific knowledge to their inferences about the fossils. Further, students communicated and justified their findings about the fossils to the rest of their class. Clearly, these aspects of the Fossil Finders curriculum provided students opportunity to experience these features of inquiry; however, students in Monica's classroom did not enact the full potential scope of the investigation in the curriculum. For example, video and other data indicate Monica stressed more of the data collection aspects of the Fossil Finders curriculum and directed less attention to aggregate data analysis. This limited use of inquiry could be attributed to the teacher's developing and fragile views of inquiry, or to her view of her students' developmental levels. She may not have believed her students capable of the more advanced levels of interpreting the data. This instructional approach impacted the extent to which students were fully involved in the investigation and in inquiry with respect to the investigation. These findings fall in line with the literature pointing out the shortfalls of citizen science-based research, where participants are oftentimes not involved in the full activities of science beyond data collection (Bonney et al., 2009). Though students did not experience full levels of involvement in scientific research through their participation in the Fossil Finders investigation, I make the case that they did in fact experience aspects of the essential features of inquiry as articulated by the NRC (1996; 2000). To this end, I argue that there may be differing levels of involvement in inquiry and that inquiry can be applied to discussing various types of activities conducted by scientists.

During Monica's implementation of the Fossil Finders investigation, students handled fossil samples, identified and measured these fossils, and compiled data sheets



with their identifications and measurements. Though students engaged in these aspects of data collection, instruction did not extend far enough for them to investigate the aggregate data and “big picture” questions about the fossils. This experience would have provided students with the opportunity to raise scientifically oriented questions related to the different groups of fossils found by the class; and to compare their class data with data from other classes involved in the project. For example, students might have asked and investigated whether the same fossil types and size distributions were in another rock type, which would indicate other environmental conditions. Though these extended research questions did not occur, students addressed the overarching research question driving the Fossil Finders investigation, as described above, and conducted their own processes of data analysis, guided by their teacher, during the data collection phases of this work. However, in this case, the scope of data analysis consisted of viewing each individual fossil sample as data rather than the compiled data in its aggregate form. Students thus conducted a comparative analysis between different types of fossils as they collected data for the scientists. These aspects of data analysis are consistent with age level appropriate learning progressions about evolutionary concepts proposed by Catley et al. (2005). The authors suggest that students at the 5th grade level should be able to differentiate organisms by their features and consider the environment that its characteristics were adapted to. Further, while researchers found middle-school student understandings of scientific evidence and the data collection process to be weak (Jeong, Songer, & Lee, 2007), findings related to this study suggest that middle school students may, in fact, achieve learning gains through involvement with scientific data.

Other data provide examples of how the features of inquiry were distributed across the Fossil Finders investigation and to what extent each aspect was implemented. For example, during the days in which the Tricky Tracks instructional activity was being

implemented, an analysis of conversational turns, or verbal exchanges between speakers, indicated that students engaged in connecting their explanations to scientific evidence most, while other aspects of inquiry were not as evident. Of all features of inquiry, students least demonstrated the instantiation of pursuing scientifically oriented questions and communicating and justifying their findings during this time. While these findings may not be representative of the features of inquiry addressed during other instructional days in the unit, they raise a number of questions related to Monica's use of inquiry for other activities within the curriculum. For example, was Monica limited from engaging students in other scientifically oriented questions during this activity because the class was already pursuing a pre-determined research question? Or, were time constraints a limiting factor? Or perhaps, it could have been Monica's abilities, given her newly acquitted understandings of the geological concepts, NOS, and inquiry approaches as a result of professional development over the summer prior to the curricular implementation.

Data indicate that either of these was the case and that trends found in the Tricky Tracks activity were also characteristic of Monica's general instructional approach. For instance, both the Tricky Tracks activity and the Fossil Finders investigation were guided by pre-determined questions. Consequently, students may not have had opportunity to pose their own research questions. Further, when students did raise questions about fossils they could have been investigated, Monica did not appear to encourage them to do so. Examples of this beyond the scope of the Tricky Tracks activity include when a student used her sense of smell to observe fossils and another decided to cover them with water to see if more fossils would be visible. For example, do all rocks look the same when they are wet, and do all of the rocks smell the same? Though students asked these questions, Monica did not set up official class time for students to pursue research related to their questions.

An instructional environment that did not allow students to pursue smaller research questions may have been directly related to fewer opportunities for students to communicate and justify findings across the unit. It is likely that Monica's inability to fully involve students in components of the Fossil Finders investigation have been related to time limitations. As the literature discusses, time constraints are among the greatest challenges for implementing inquiry and inquiry-based investigations (Baker, Lang, & Lawson, 2002). Monica commented on the fact that instruction was already taking longer than she thought it would. Based on time limitations, Monica decided that she would need to enter students' fossil measurements into the database herself. Consequently, students were not a part of the process of compiling aggregate data or completing an analysis of these data. These time limitations may correspond with the fact Monica was not able to fully engage in all aspects of the investigation, let alone provide opportunities for them to pursue other research questions.

It is important to also consider the pilot nature of this curriculum and that the online database used for aggregate data analysis in the curriculum was still under construction at the time of the summer professional development. Thus, instructing teachers on how to use the aggregate data in the database was not part of the professional development program. It is very likely that as a teacher with little experience in science involved in this investigation, Monica was also not yet comfortable in conducting data analysis using the database. This falls in line with the literature describing the challenges to novice teachers implementing inquiry (Crawford, 2007) and the need for professional development. Interestingly, this also points to the importance of learning through participation in science (Rogoff, 1995). Monica was able to engage in and transmit the very aspects of inquiry that she herself was involved in, with respect to the Fossil Finders investigation.

Beyond Monica's use of features of inquiry and the scope of data analysis in her classroom during the Fossil Finders unit, there was evidence that Monica's instructional approach shifted from a teacher-directed to student-centered approach through her questioning strategies. For example, in early lessons, conversations demonstrated Monica as the main source of knowledge. As the instructional unit progressed, Monica opened up more opportunities to engage in exploring students' questions. Toward the end of the curriculum, Monica probed students once again, but rather than affirming the validity of their responses, she asked students' for their rationale. In this way, she stepped back from her role as expert and gave more opportunity to her students to figure out the answers by using guiding questions. This spectrum of question-asking strategies indicates moving from a teacher-directed approach in the introductory phases of the unit, to a student-centered approach during the exploratory phases of the unit, followed by an evaluative setting that merged between a teacher-directed and student-centered approach.

This shift coincided with developing student agency in the classroom. First, students responded to probes from their teacher. Student involvement in classroom activities did not stem beyond the guided instruction of their teacher. As instruction progressed, students began to ask and independently pursue their own questions. For instance, in the example above, the student actually did cover the fossil sample with water though this was not officially part of Monica's teaching or instructional approach. Students were thus engaged in making connections between their understandings and new learning. Last, students not only responded to probes, but also provided rationale to defend their thinking. These shifting questioning strategies aligned with greater use of inquiry in the classroom, where the teacher assumed the role of a learning facilitator, but also held students accountable for their findings along the lines of inquiry. Thus, this instructional approach supported students in

developing academic identities (Nasir & Saxe, 2003). The teacher's use of questioning and student agency in response establish this classroom embrace the characteristics of inquiry, with teachers assuming a facilitation role over time (Crawford, 2000).

Through video data evidence, it is clear that Monica both attempted and struggled to embrace an inquiry-based instructional approach in her classroom. Though Monica implemented many features of inquiry, these features were not always consistent. For instance, as students were mainly focusing on data collection through the context of the investigation, and there was little opportunity to construct claims and use data to support them. Though I argue that students comparatively analyzed fossil samples, not all aspects of inquiry were implemented to the fullest extent possible within the scope of the Fossil Finders investigation. These challenges fall in line with literature that describes the complexities and possibilities of novice teachers implementing inquiry-based instruction (Crawford, 2007; Marx et al., 2004; Songer, Lee, & McDonald, 2003). Monica, however, demonstrated a shift in her instructional approach and repositioning her role as a teacher to embrace an instructional approach more conducive to inquiry (Crawford, 2000). Through her questioning strategies, Monica became more of a learning facilitator rather than a source of knowledge. Students were thereby engaged in sharing scientific authority with their teacher, a feature of IC (Luykx & Lee, 2007) and developing academic identities. These academic identities positioned students as learners who made use of both everyday and scientific language and ways of knowing to identify fossil samples—an non-everyday activity with non-everyday objects. Student agency was thus positioned to transcend the borders between students' initial perceptions of scientific work and newly formed understandings of NOS. Ultimately, this instructional approach also better aligns with understandings about NOS, where scientific knowledge is tentative,

or not held by an authority, and constructed by the participants of scientific activities (Lederman, 2004) than a traditional instructional approach in science.

### *Instructional Congruency in the Classroom*

Monica consistently made use of features of IC as a part of her teaching throughout the implementation of the Fossil Finders unit (Luykx & Lee, 2007). Two of these features consider linguistic support; the use of home languages in the classroom and linguistic scaffolding to enhance meaning. Both of these features of IC were evident throughout the Fossil Finders unit, and an analysis of Tricky Tracks instruction pointed to the use of linguistic scaffolding to enhance meaning in more detail. Given the dual-language focus of the classroom, this was the anticipated case.

In her attempt to reach English-language learners, Monica consistently made use of literacy strategies while teaching science (Lee & Fradd, 1996). Examples of this included the use of a word wall, or vocabulary used in the classroom posted in a visible space, illustrations during instruction, and pronouncing new terms together with the class. She also provided students with scaffolding when it came to story writing and explicitly pointing out the relationships of text materials to everyday life and other texts. This included the use of graphic organizers when writing the Tricky Tracks stories, explanations of what needed to be included in notes, and probing students to make connections between text materials. These instructional approaches align with literature on instructional approaches for second-language acquisition (Cummins, 1994).

However, English remained Monica's primary language used for science instruction and of all the features of IC, the use of home language was least evident in the context of her classroom. She nonetheless provided students with one-on-one additional guidance in Spanish and welcomed students to use Spanish language for

writing notes. Video provided evidence of students informally conducting group-work in Spanish, which included having discussions about fossils and dinosaurs as well as jovial off-topic chatter.

Other features of IC relate more directly to science instruction and cultural exchange, such as the sharing of scientific authority and the use of diverse cultural experiences and materials during instruction. Monica's instructional approach was inclusive of these features of IC during the Fossil Finders unit. A detailed analysis of the Tricky Tracks activity pointed to Monica's emphasis on sharing scientific authority with her students. Instructional moments throughout the rest of the unit were also indicative of Monica consistently sharing scientific authority with students. Examples of this included Monica relying on students to pronounce scientific terms, building from students' observations and explanations, and withholding from evaluating incorrect student interpretations. In all of these instances, Monica repositioned herself from being the scientific authority and source of knowledge in the classroom, to a learning facilitator. Interestingly, the implementation of this instructional approach also aligns with the constructivist aspects of inquiry (Driver, et al., 1994).

The use of diverse cultural experiences and materials was less frequent, but nonetheless observed in Monica's classroom. Many times, Monica brought in examples from students' everyday lives, which were reflective of their everyday mainstream and ethnic cultural experiences. This instructional approach aligns with Aikenhead's (1996) considerations of school science as being a sub-culture apart from everyday life experiences. Monica's instructional approach included bridging between the two. For example, when Raul suggested that a lemur could be an example of a prehistoric animal, based on a movie he saw, Monica was able to turn this into a teachable moment. She went on to describe the difference between science

and what students may see in movies. As described above, Monica also drew on other examples to frame content matter learning. For example, when students had questions about whether a clam was a plant or animal, Monica asked them if they had ever eaten anything from the sea. Students quickly connected their everyday, and possibly cultural, experiences to science learning and recognized a clam as an animal. Monica also took opportunities to connect understandings about climate to students' life experiences with either living in or traveling to Puerto Rico. Monica thus made use of teachable moments to make links between students' everyday life and science, as well as scientific practice during the Fossil Finders instructional unit. Together, these examples of the verbal exchanges that took place in Monica's classroom and the examples reviewed above substantiate the regular use of IC in Monica's classroom. This provides the basis to consider how this instructional approach can be combined with inquiry and explicit instruction in NOS. To date, there are no examples of this combined instructional approach in the literature.

#### *Explicit Instruction in NOS in the Classroom*

Video data of the Fossil Finders instructional unit provides evidence of Monica addressing all five features of the NOS focus construct (Table 5). Monica embedded these features across the instructional unit and made use of the Tricky Tracks activity to teach NOS concepts, in particular.

In the Tricky Tracks activity, students came up with different explanations for what had occurred in the Tricky Tracks scenario. Monica drew from this example to illustrate the subjective and interpretive features of NOS. The aspect of NOS most emphasized in Monica's classroom was that science is based on human inference, imagination, and creativity. The Tricky Tracks story writing activity, where Monica extended student observations of the tracks across the overhead slide into a literacy



activity, served to reinforce conceptions of science and the work of scientists as imaginative and creative. Moreover, she embedded other important aspects of NOS into instruction, such as the distinction between observations and inferences (Lederman, 2004).

However, in this instructional activity, Monica also missed several opportunities to expand on students' understandings of NOS. For example, the Tricky Tracks activity entails the teacher moving across three slides with each one providing more tracks, or evidence to construct an explanation. In this case, more evidence may in fact shift students' initial observations and explanations. In this way, the Tricky Tracks activity inherently encompasses the construct of tentativeness in science. Though Monica conducted this activity with her students, she stressed features of NOS related to the imagination and subjectivity used by scientists over the tentativeness of their explanations. Consequently, this particular feature of NOS remained *implicit* in the context of the enacted activity. This begs the question: how explicit does it need to be? And, what does explicitness mean? Some of the leading research on explicit instruction in NOS does not address these questions (Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002).

One important point must be raised related to teaching about NOS. Although Monica referred to recognizing science as a cultural way of knowing in an interview, she did not emphasize the NOS construct of science as a socially constructed body of knowledge that is influenced by the culture/s in which it is practiced during classroom instruction. This finding aligns with research related to teacher professional development in learning about NOS, where teachers made the least learning gains with respect to the social and cultural features of science in relation to the other features (Akerson, Abd-El-Khalick, & Lederman, 2000). This missing feature of NOS may have been particularly relevant to the students in this class. This is because referring

to science as way of knowing that may be influenced by the cultures in which it is practices may have encouraged students to consider their own views on science, the notion of objectivity in science, and how science may differ across different groups of people. Thus, professional development programs focused on teaching about NOS may need to pay particular attention to instruction related to the culturally influenced components of science.

While it is clear that Monica integrated instruction about a number of the features of NOS into her classroom teaching, certain aspects of NOS remained more evident than others. For example, at times Monica made clear connections between student activities and the work of scientists by referencing aspects of NOS. However, at other times, the connections between student work and science remained implicit within the NOS-related activities. Though students engaged in aspects of NOS through classroom activities and practice, Monica may not have addressed them all verbally or to the same extent in her teaching. It needs to be clear that it would not be expected for Monica to be expert in teaching all aspects of NOS, explicitly. It is a tribute to her as a teacher that she was able to address as many as she did, given her newness to this kind of thinking. These findings fall in line with research focused challenges in the instructional implementation of NOS for even a teacher with informed understandings about NOS (Akerson & Abd-El-Khalick, 2003). This study focuses on which features of NOS were being addressed through instruction for the purposes of characterizing Monica's instructional practice. Nonetheless, findings may have limitations with respect to considering the degree of explicitness in teaching about NOS. Future research may benefit from the use of an instrument developed to measure the degree of explicitness in NOS instruction.

### *Confluence of Guiding Constructs*

The above sections review the key aspects of what implementation of inquiry, IC, and NOS looked like in Monica's classroom from a functional perspective. This section first directs attention to how these three constructs and their features were brought together and the theoretical implications of constructs combined, as implemented in Monica's classroom.

Data collected in Monica's classroom illustrates an instructional approach where features of inquiry, explicit instruction in NOS, and IC were implemented, although not all features of particular constructs were implemented in full or during the same instructional episode. The Tricky Tracks activity provided a platform upon which to analyze the interaction between the three constructs, as described above. In terms of the implementation of the three constructs, data suggests that instances of IC were most frequent within this activity. It is likely that this was due to the dual-language nature of the classroom, where IC was an already adopted instructional approach, and this was not a result of the Fossil Finders instructional unit. However, NOS-oriented references or practices were more frequently noted than inquiry-oriented references or practices. This may be due to the fact that the Tricky Tracks activity focuses on NOS concepts specifically. Therefore, this is also not an unexpected result. Monica's inclusion of features of inquiry into this activity, however, reinforced how instruction in NOS fit into the larger paradigm of the Fossil Finders unit and the close alignment between NOS and inquiry.

Most instances of Monica's use of inquiry, NOS, and IC constructs were related to the days that Monica used teacher-directed instructional approach. Though these trends contradict the inherent expectations associated with inquiry-based instruction, they are partially based on data collection limitations as described above. To reiterate, with the use of only one camera, video recordings captured overall

classroom interactions on days where Monica used mainly teacher lead approaches. Thus, some moments of interaction where Monica may have made use of some of the focus features of inquiry, IC, or NOS during instruction were not captured. Nonetheless, data associated with days of direct instruction demonstrate the following trend: across Day 1, Day 2, and Day 4 of the unit, it is evident that the three constructs were grouped together in the same relative proportion (see Tables 12, 13, and 14). This approach, with instructional emphasizing IC, followed explicit instruction in NOS and then inquiry, is thus characteristic of Monica's classroom, with respect to the Tricky Tracks activity. Instructional episodes related to this activity, when grouped together, help also make the case for how inquiry, IC, and explicit instruction in NOS were brought together in this instructional setting.

Throughout the rest of the instructional unit, features of inquiry, IC, and NOS overlapped and reinforced one another. For example, Monica touched upon several focus constructs and their features when she extended Tricky Tracks into a story-writing assignment focused on student explanations, a feature of inquiry. Students were instructed to write stories about their inferences related to the tracks, as described above. To this end, Monica explained that scientists have “different perspectives” or “stories,” and also “different theories,” of what may have occurred even though they have the same facts (October 6, 2008; line 375). Though Monica made the case for the subjective nature of science, a feature of NOS, her interchangeable use of the terms “theories” and “stories” is problematic with respect to the literature on NOS. Lederman (2004) explains scientific theories are “*inferred explanations* for observable phenomena... [and] serve important roles, such as guiding investigations and generating new research problems in addition to explaining relatively huge sets of seemingly unrelated observations in more than one field of investigation (p. 305). However, he does not describe scientific theories as stories.

While Monica's instructional approach is somewhat problematic with respect to the literature on NOS, it aligns with making NOS more accessible to students' everyday understandings, a feature of IC. For example, though students may not understand what a theory is in scientific terms, it is highly likely that they would know what a story is. In likening theories to stories, Monica essentially repacks scientific ways of knowing into a context that is familiar to students; however, one that may or may not frame science within its own paradigm. Though contextualized links were formed between scientific ways of knowing and student understandings, framing aspects of science outside their paradigm may have served to misguide students' understandings of science. When Monica assigned students to write and share their own "stories," or versions of what could have occurred in the Tricky Tracks scenario, she also effectively incorporated the sharing of scientific authority with students and provided them with structures for writing, or linguistic scaffolding. In this way, Monica was able to integrate explicit instruction in NOS with other features of IC.

Monica's instructional approach also included positioning students as researchers helping scientists conduct an authentic investigation. This aspect of her instructional approach overlapped with IC and inquiry, as well as explicit instruction in NOS, but may have challenged students' home and cultural ways of knowing. Monica promoted a scientific identity for students to take on for the course of the Fossil Finders unit and used it to engage her students in the practices of scientists. For example, when Monica framed her students as researchers, she justified the need for their careful observation, measurement, and working with data, in other words that they adhere to scientific practices. These practices correspond with the NOS construct that science is empirically based. Monica's positioning of her students also allowed her to consistently compare what they were doing with the nature of scientific work. In another instance, Monica made the case for students to double-check their work

because this is what scientists do. This instructional approach is pertinent to considering how Monica began to bridge and overlap between the theoretical constructs guiding this research. For example, theories of social reconstruction point to individuals valuing and assuming the identities held within their communities (Holland et al., 1998). Through this instructional approach, Monica attempted to assign value to an academic, or scientific, identity within a school community modeling a community of scientists. This instructional approach thus makes an effort to produce or reproduce the values of the scientific community within the classroom and to create the space for students to assume scientific identities. While this instructional approach supported the potential that students could become scientists, it also advocated for students to adopt scientific practices and ways of knowing. This may have in fact served to challenge students' everyday ways of knowing and conflicted with differing notions of identity.

Further, not all features of the three focus constructs observed positively reinforced one another within the context of this unit. For example, when students constructed explanations for what they thought had occurred in the Tricky Tracks scenario, they did not always demonstrate connecting their explanations to evidence or to scientific knowledge, two features of inquiry. Further, though Monica encouraged students to develop explanations based on imagination, in accordance with features of NOS, these explanations were oftentimes fictitious and based on anthropomorphic constructions from everyday life. For example, Carolina, a student in Monica's class, shared that one of the dinosaurs from the Tricky Tracks "went back home and never bothered the other dinosaur again" (September 21, 2008, line 201). Monica used this scenario as a teachable moment to explain that the tracks did not show evidence of one of the dinosaurs "turning around to go home." Moreover, she explained that they would later learn about the food-chain and predator-prey relationships. Through this,

Monica essentially addressed the need for evidence in formulating explanations and made features of NOS explicit. However, by validating scientific knowledge, Monica effectively challenged how students brought their everyday understandings and cultural experiences into science learning, as well as their scientific authority, all features of IC.

The tensions made evident through combining inquiry with IC and NOS create moments of opportunity to negotiate scientific understandings in relation to everyday knowledge. Future work in mapping how these instructional moments correspond with one another within and across episodes will reveal greater detail on the complex interrelationships between the constructs that the instructional model combining inquiry with IC and NOS suggests. Additionally, further conceptualization on the extent of explicitness in NOS during instruction is necessary. Currently, there is no measure to consider what explicitness means and the degree to which instruction may be explicit. The Tricky Tracks activity provides opportunities to address the culture of science through NOS; however, further research is needed to determine the degree to which the links between NOS-related instruction and the work of scientists were made explicit.

*Summary: Understanding the Instructional Context of Monica's Classroom*

An understanding of the enacted curriculum in Monica's classroom provides grounds to analyze the feasibility of implementing an instructional model combining inquiry, IC and explicit instruction in NOS. Monica's background preparation to teach science in her classroom is representative of 5<sup>th</sup> grade teachers. Though she was enthusiastic about bringing science into her classroom, she was not entirely confident in her abilities to engage students in inquiry. Following a summer professional development session, Monica was able to carry out many of the activities she and

other teachers experienced as learners during the summer. These activities, however, did not include working through the database and in-depth data analysis.

Coincidentally, these are two components of the curriculum that Monica did not implement with her students, partially due to time constraints.

Monica's classroom, nonetheless, serves to inform what may be possible in terms of innovative approaches to science teaching and learning to support underrepresented students. How Monica implemented components of the Fossil Finders curriculum is the focus of this analysis. By engaging her students in an authentic scientific investigation, Monica made a significant point of departure from traditional instruction in science. Moreover, through her attempts to reposition herself as a learning facilitator, rather than the ultimate source of knowledge, she engaged students in co-constructing understandings about science. Monica also made various features of NOS explicit through instruction, a significant step toward framing science content within its paradigm. As a teacher working in a bilingual classroom setting and making use of many strategies for IC, she also demonstrated how these separate constructs of the approach conceptualized in this study can be merged. Monica thus shows what is possible in a middle school classroom and where, perhaps, further teacher support is needed toward science instruction framing science as a cultural way of knowing.

An overview of the instruction and interactional exchanges that occurred in Monica's classroom help frame the discussion centered around student experiences in a classroom practicing IC and attempting to implement an authentic investigation using inquiry and explicit instruction in NOS in the next section of this chapter. The discussion above focused on Monica's instructional moves and how she presented new information and engaged students in learning. However, it is important to recognize that students, too, played a role in shaping Monica's instructional approach and the



context of their classroom. Monica's approach in establishing the classroom context and student responses are inseparable; however, the two were artificially divided in order to better understand 1) how the teacher was able to bring together the theoretical constructs guiding this work, and 2) to conduct closer observations of both teacher instructional turns and student responses as possibly stemming from differing cultural spaces. The discussion that follows focuses on student responses to instruction and how their science learning experiences may have been shaped by this particular instructional setting.

### ***Discussion of Findings Related to Student Experiences***

The underlying purpose of this research was to consider an instructional approach that may bring together innovative instructional approaches from different fields to engage underrepresented students in science learning and foster better understandings of science. This section discusses findings related to the question: *How did underrepresented students experience and respond to an instructional approach combining inquiry, IC, and explicit instruction in NOS?* This includes how students may engage in inquiry, how students bridge between their everyday understandings and science, students' views about inquiry and NOS, and ultimately, what students may learn as a result of this instructional approach. These considerations formed the four sub-questions guiding this portion of the study:

- 1) In what ways do students engage in scientific inquiry?
- 2) How do students bridge everyday understandings and science?
- 3) What are students' views about NOS and how do these change during the investigation?
- 4) How are students supported in content-area learning?

Findings related to these research sub-questions (Table 15) present different aspects of student experiences in the context of Monica's classroom and the Fossil Finders curriculum. In this section, I further discuss these findings in three narrative sections with respect to theory, the instructional approach used by the teacher, and other emergent findings. The three main segments of this discussion include: 1) cultural influences on perceptions of science and science learning, 2) experiencing the scientific community of practice, and 3) student content-matter learning about science.

### *Cultural Influences on Perceptions of Science and Science Learning*

Findings across sub-research questions as illustrated in Table 15 above demonstrate that students came into the context of the Fossil Finders instructional unit with previously shaped notions about science, as well as the everyday understandings they used to make sense of science. Moreover, findings indicate that student understandings about science were formed by everyday life experiences and their previous and classroom science learning experiences. Together with other emergent findings (Table 19), these findings make the case for instructional approaches connecting to and building from students' culturally shaped understandings about science (Aikenhead, 1996; Lipka et al., 1998). Across these findings, the following theme begins to emerge: *students come into science learning environments with science understandings shaped by mainstream culture and use these understandings to make sense of science instruction*. The following findings based on student experiences, as well as emergent findings related to parent understandings about science, come together to support this developing theme:

**Table 21. Findings Related to Cultural Experiences**

<b>Findings</b>	<b>Type</b>
<ul style="list-style-type: none"><li>• Students had preconceived notions about science; some of these views held science and the work of scientists separate from school science learning</li></ul>	<i>Student Experience</i>
<ul style="list-style-type: none"><li>• Students drew from everyday life examples to talk about science during class time.</li></ul>	<i>Student Experience</i>
<ul style="list-style-type: none"><li>• Parents' indicated varied views and skepticism about science</li></ul>	<i>Emergent</i>
<ul style="list-style-type: none"><li>• Parents expressed wanting their children to experience active instruction that would engage them in learning science.</li></ul>	<i>Emergent</i>

A conversation about the cultural influences on student understandings about science begs the following questions: What are cultural influences on science understandings? What are the cultural backgrounds of students? And, what shapes students' perceptions of science and what they consider to be the work of scientists? To consider these questions, the findings of this study are brought into conversation with Gutierrez and Rogoff's (2003) notions of culture, where culture is dynamic and shifting and embedded within the activities of a community. Rather than a set of fixed cultural traits across a group of people, this perspective considers an individual within the cultural practices of a community. Within this perspective, "individuals' background experiences, together with their interests, may prepare them for knowing how to engage in particular forms of language and literacy activities... according to specific community-organized approaches" (p. 22). This discussion relies on how the cultural activities of students outside of school settings may prepare them to engage in science. This includes the understandings of science that students may bring into the

classroom, based on activities in their regular school, home, and community experiences.

As a part of this study, parents were interviewed about their views of science and science instruction to establish a better understanding of the students' backgrounds and home contexts, which may play a role in shaping student understandings about science. These findings contribute to an understanding of the how students' parents perceive home cultural activities in relation to school learning and school science (Appendix K). For example, while parents themselves held differing views about science, including skepticism about the authority of scientists, they wanted the best science learning environments for their children. Parents shared sentiments regarding active learning as being beneficial to maintaining students' interest in science and to their development as learners. They also raised examples of how authentic and experiential learning opportunities such as having class visits and hands-on opportunities could be useful. While these examples were generally supportive of science learning for students, they positioned schools as the place where science learning occurs. In this way, parents illustrated a lack of recognition for the potential for scientific activities to cross boundaries between home, school, and the scientific enterprise.

Nonetheless, other parent responses to interview questions (Appendix J) provided examples through which activities and learning could be linked. Raul's mother described home and family-based activities such as going to the movies, cooking, and house projects. In class, Raul drew an example of a prehistoric animal he had seen in a movie. In this, Raul's family involved Raul in the activities of mainstream culture, which in turn, shaped Raul's views about science. This example extends Gutierrez and Rogoff's (2003) examples of repertoires of practice to include participation in mainstream culture. Establishing mainstream culture as a part of

students' everyday and cultural experiences is an important component to repositioning the focus students from categorizations such as Latinos, ELL students, and/or underrepresented students, to students whose home-based cultures are also dynamically influenced by mainstream culture. This mainstream culture, in turn, may also shape students' understandings of science, as well as their views and perceptions of science.

During classroom instruction, Monica indicated she strived to build on her students' understandings that may have been shaped by previous knowledge, mainstream culture and home-based cultural practices. This included students recalling prehistoric animals as a part of the Tricky Tracks activity, as described above. When Monica asked students to recall prehistoric animals they were aware of, students relied on prior knowledge to respond to her question and verbalize a list of animals. It is evident that part of this knowledge is based on participating in mainstream culture from of Raul in the example above, who suggested a lemur as an example of a prehistoric animal based on a movie he saw. In other example, students were able to discern between clams being animals or plants based on other home-based practices, such as eating seafood. These examples indicate students using culturally established knowledge to make sense of new science content. Monica also worked to bridge the divide between school-based science and everyday understandings by proposing explanations based on other mainstream knowledge. In this way, the integration of everyday and culturally-based understandings about science *content* can serve to facilitate science learning. Content-matter may perhaps more easily traverse across different spaces. This is not the case, however, when considering understandings about scientific processes.

Students did not demonstrate having informed understandings about the processes of science and activities of scientists, based on home and cultural ways of

knowing as well as mainstream understandings. Mainstream portrayals of the work of scientists may have largely shaped their views and partially formed the cultural backgrounds from which students, in turn, negotiated their understandings about science. However, mainstream and media portrayals of the work of scientists, as related to “discovery,” “inventions,” and “experiments” oftentimes do not realistically reflect the other and perhaps tedious processes of science, such as observation, data collection, and data analysis realistically. Consequently, students’ views of science may have been formed outside of any of the components that situate actual scientific knowledge (Brown, Collins, & Duguid, 1989).

Unfortunately, these misconceptions may become reinforced by traditional classroom science teaching environments. In traditional classroom science instruction, students rarely engage in actual scientific practices. Prior to initiating the Fossil Finders unit, both Paula and Alyssa equated science education to learning out of a book. For Paula, learning science was listening to her teacher. It is evident that these notions about science were also formed outside of the context of authentic scientific activity and culture. Students had not actively participated in authentic science, and thus used other frameworks and contexts to construct their understandings about science and scientists.

These findings, together, make the case for *redefining* the culture of influence on students’ understandings of science. Though these students come from backgrounds that are underrepresented in the sciences, there were few examples of students drawing on home-based ways of knowing to make sense of science. Moreover, as described above, interviews with parents indicated that these students primarily come from home environments that situated science learning as a school-based activity. For example, though parents had differing views on science, they situated school as the place for science learning to occur. In interviews with parents,

home practices, or home-based culture, did not make reference to scientific activity. Along these lines, there was little evidence of students making links between home ways of knowing and scientific ways of knowing. Mainstream culture, however, provided examples of linkages between science instruction and everyday knowledge and practices. For example, parents discussed problem-solving as looking things up online. Students gave examples of prehistoric animals they saw in movies. These examples indicate the dynamic nature of culture and its ability to shape and be shaped by the activities within a community. Though many of the parents of children in Monica's classroom were first or second-generation immigrants, their evolving cultural identities differed from the cultural traditions they chose to maintain in their homes.

Greater student connections to science were evident through examples from mainstream culture, whereas Spanish language was used as more of a communicative tool in this classroom setting. These observations point to the following: 1) the divide between home-based environments and school science, and 2) mainstream culture as a bridge between the two. Nonetheless, the mainstream cultural portrayals of science brought into the classroom were decontextualized from actual scientific activity and practice and in some instances served to misguide student understandings about science. Given the importance of school for shaping student perceptions about science to underrepresented students in particular, these findings make the case for school-based settings providing authentic science learning experiences for students to better frame the activities of science within scientific practice.

#### *Participation in a Scientific Community of Practice*

Students' culturally-influenced backgrounds and preconceived notions about science, as described above, make the case for science to be taught within the context

of scientific activity and culture. These findings also frame scientific knowledge as situated, where the activities, context, and culture of a particular field are inseparable from the knowledge held within it (Brown et al., 1989).

As an instructional approach, authentic investigation forms a context for student learning about scientific activity and framing scientific knowledge. Scientific culture can be learned through participation in the activities of inquiry (Driver et al., 1994), provided it is made explicit (Lederman, 2004). These theoretical views on science learning point to student involvement in the authentic activities of science, as an integral part to learning scientific content-matter, processes, and ways of knowing. However, to provide an authentic context for science learning, the scientific community of practice must be accessed (Lave & Wenger, 1991). This is because practices of students in even innovative school science learning environments and those of scientists in their work environments differ (Chinn & Malhotra, 2002).

While the purposes of scientific investigation may differ between students and scientists, this study provides some evidence that a shift toward more authentic instruction in science in school settings can benefit students. For example, in this classroom the introduction of an authentic research investigation allowed students to experience certain components of the scientific community of practice firsthand. This included interacting with the scientists running the investigation both within the classroom setting and through online correspondence. The learning environment of this urban middle school classroom thus made a point of departure from traditional instructional approaches employed in most middle school settings. It can be argued that the following emergent findings and findings based on students' experiences (presented above) suggest that this learning environment more closely models authentic scientific practices and links to the scientific community of practice:



- *Students from underrepresented populations engaged in the various aspects of inquiry across the span of the curriculum unit.*
- *Students had preconceived notions about science... some of these views about science and students' self-identification as scientists shifted as a result of participating in an authentic investigation.*
- *Students demonstrated changes in their views about science, NOS, and what scientists do following inquiry-based learning experiences and a scientist's classroom visit.*
- *When a scientist visited the class, this impacted students' views on science and enhanced their interests in pursuing scientific careers.*

Across these findings, the following theme begins to emerge: *inquiry-based classroom learning experiences in this classroom involved students from underrepresented backgrounds in the scientific community of practice and shaped student perceptions about science.*

Monica's classroom was involved in all of the features of inquiry (NRC, 2000) throughout the course of the Fossil Finders instructional unit as described in the Results section. Through an inquiry-based instructional approach, students had opportunities to engage in the practices of science and model the activities of practicing scientists. What is debatable, however, is the extent to which individual students engaged in inquiry and how its use impacted them. Because the classroom collective was the focus of this study with attention drawn to only certain focus students, the nature of the classroom more broadly and the stories of a handful of students shapes the scope of possible analysis. Broad data, with respect to the classroom, provides important clues to how an inquiry-based activity may serve as an intermediary space in which differing understandings may be negotiated. For

example, an analysis of the interactional turns related to the Tricky Tracks activity indicated that the collective classroom was involved in most aspects of inquiry to the same extent; however, it made twice as many interactional turns related to the feature of connecting explanations to scientific knowledge in inquiry. In this sense, inquiry may have been used as a vehicle for bridging classroom learning experiences to the greater scientific enterprise. This, in combination with students making use of everyday culture to make sense of science as described above, builds a case for inquiry as an instructional approach that provides opportunities for negotiating differing understandings—across everyday life, school, and the scientific enterprise.

Monica's classroom also provided examples of how structuring a learning environment through inquiry may occur. By virtue of engaging underrepresented students in the practices of science, the classroom was in essence developing an instructional setting more closely modeling the authentic practices of scientists and providing students with learning *opportunities* to engage in the scientific CoP. These activities converged with the everyday understandings about science and science content-matter that students brought along into the classroom. Monica's instructional approach, which combined IC and explicit instruction in NOS with inquiry, is paramount to differentiating inquiry-based instruction from forced enculturation into science. By increasing student access to science through linguistic scaffolding, drawing from students' cultural understandings, and embedding dialogue about what scientists do as a part of instruction, the combined instructional approach provided greater opportunities for students to experience aspects of science. Whether or not all students engaged in scientific activities and to what degree remains uncertain. However, evidence gathered from individual focus students reflects shifts in students' views about science following participation in this learning experience. Therefore, the

assumption that the interviewed focus students were engaged in most or some of the features of inquiry drives the remainder of this discussion.

Focus students in Monica's classroom exhibited experience-based changes in their views about science, based on participation in an authentic investigation that made use of inquiry. After being involved in the Fossil Finders instructional unit, which included an authentic research question, the use of data, and interaction with paleontologists, students expressed changes in their views about what science is. For example, some of the focus students initially thought that science was learning from a book or listening to what your teacher said, as described above. Further, students indicated shifting views from science as a subject to science as a practice that included "observing, making inferences, [and] figuring out experiments" [sic] (Bianca, VNOS-E post-test). These shifts demonstrate learning and accompany the inquiry-based practices that students participated in. In this way, it can be inferred that student experiences, as related to participating in the authentic activities of science, drive perceptions about science.

It is interesting to note that findings related to student perceptions about science aligned with the activities that students were actually involved in throughout the course of the Fossil Finders instructional unit. As described above, students sorted through fossil samples, identified, measured, and recorded fossil data during the instructional unit. Through this participatory experience, students effectively contributed to the scientific process and co-constructed scientific understandings. For example, student groups were positioned as experts who would be able to correctly identify and measure their fossil samples. Further, students were aware of the fact that the collective classroom data and findings would inform the work of scientists. In this way, students were provided with opportunities to be included in the scientific process of knowledge construction. However, due to time constraints, data analysis was not

part of the instructional focus in Monica's classroom. Student responses to interview questions reflected that while students understood the observational aspects of science, they were uncertain of what scientists did with data once it was gathered. This suggests that students' inability to respond to questions about how scientists use data most likely relates directly to the limitations of their classroom learning experiences. These findings point to student learning with respect to the activities in they were involved in, and the importance of an authentic investigation for framing scientific activities.

A scientist's visit to the classroom provided students with even greater access to a practicing member of the scientific community. As described above, the scientist shared her perceptions about being a scientist and answered student questions about the particular research she was involved in. She also commented on the student questions she received online the previous day through the "Ask a Scientist" component of the project website. Through this classroom exchange, the classroom learning environment actually intersected with that of the scientific community, rather than through the virtual avenues established by the Fossil Finders project. This interaction, combined with participation in an authentic investigation, proved to influence students' views about science and their own self-efficacy as potential scientists.

Focus students demonstrated changes in their understandings about science through learning experiences that increased their access to the scientific CoP, as described above. Without directly involving these students in authentic research, with students as active participants in scientific processes and in contact with practicing scientists, it is questionable whether students would have developed these views. Rather, existing views about science would likely be reinforced through both mainstream views on science and traditional classroom-based science instruction.

Students also demonstrated developing more agency as potential scientists following active participation in the activities of science and interaction as scientist (Holland et al., 1998). Following classroom experiences using inquiry, focus students began to self-identify as scientists. As described in the results section, Raul provided rationale for describing himself and the rest of the classroom as scientists. “We’re basically doing the same thing” as scientists, he stated. His reasoning rested upon the fact that the classroom was involved in an authentic investigation, therefore as participants in the activities of scientists, students became scientists. Focus students also demonstrated an interest in pursuing paleontology after meeting the scientist. Bianca, who in her first interview had self-identified as a non-scientist because she was “not that good at science,” later indicated wanting to become a paleontologist in her follow-up interview. These student reflections substantiate the claim that their participation in the activities of science and interaction with the scientific CoP established better understandings of science and may have helped these students see themselves within the sphere of the scientific community.

Increased access to the scientific community, in turn provided opportunities for students to negotiate their everyday and cultural understandings about science within the actual activities, context, and culture of science. In this sense, this instructional approach facilitated the mediation of cultural differences, between everyday ways of knowing and scientific ways of knowing (Roth & Calabrese Barton, 2004). This reinforces literature calling for the need for science instruction to be framed within a cultural space for students from multicultural backgrounds (Gallard, 1993). Instead of dictating this mediation, the instructional approach used in this classroom setting provided students with *opportunities* to expand on their mainstream and everyday understandings about science through actual scientific practice.

Two schools of thought come together when considering the theoretical implications of engaging students in such a CoP from a cultural perspective. In accordance with ecological learning theory, the classroom environment provided students with opportunities, or *affordances*, to experiment with using an appropriate *effectivity set*, or the reciprocal skills needed, within the scientific paradigm (Barab & Roth, 2006). In this case, affordances would entail participation in the classroom activities while the effectivity set would entail the features of inquiry and an understanding of NOS. Classroom instruction using IC would also provide greater affordances for diverse students to participate in science learning. However, from multicultural standpoint, the instructional approach used in the Fossil Finders curriculum unit still favors the scientific paradigm. Students, for instance, were being indoctrinated into scientific activities and ways of knowing within this learning environment. However, with Monica framing the activity as authentic and exposing students to the practices of scientists while maintaining instruction about NOS, students were *invited* to participate in science, that is, science as a particular way of knowing. This maintained science as the central learning focus, yet with the added features of IC, also drew from students' everyday ways of knowing. Rather than forcing students to assimilate into the scientific CoP or accommodate scientific ways of knowing, this instructional approach was structured toward increasing the accessibility of science and allowing students to make sense of science, as framed within its own paradigm, on their own cultural and everyday terms.

Findings from this research study also uphold the emergent theme: *inquiry-based classroom learning experiences involve students in the scientific community of practice*. As an approach to science learning, student participation in scientific activity through inquiry frames scientific knowledge and culture within an authentic context. Ecological learning theory provides functional rationale for how this learning

environment may provide students with opportunities to participate in and implement scientific practices.

Together, these form an argument for moving science instruction toward providing authentic science learning experiences, inclusive of inquiry as activity, investigation as context, and explicit instruction in NOS as culture (Chinn & Malhotra, 2002). Without an authentic context for science instruction, student understandings of science may be framed by mainstream culture or traditional forms of science instruction. An instructional approach involving students in the practices of the scientific community by way of increasing opportunities for participation in the activities of science and better portraying the field of science as an integral component of science instruction, may in turn shape student perceptions about science as indicated by results.

#### *Student Learning about Science*

Students demonstrated having culturally-influenced and preconceived notions about science, as described above. Recognition for the cultural influences that shape understandings about science, including influences from mainstream culture, makes the case for school science to be taught within the context of scientific culture. Along these lines, traditional notions of science instruction can be challenged when greater attention is directed to what students' perceptions about science may be, if developed out of context. Findings from this study suggest that science learning environments bringing together the culture, context, and activities of science foster learning opportunities for students to negotiate understandings between everyday life and science. Because of the interconnected relationship between the classroom environment and student learning experiences, it is likely that the combined instructional approach in this classroom influenced student learning. Drawing from

the following findings, I make the case that student learning was influenced by the instructional approach used in this classroom:

- *Interviews with focus students indicated students began to view science as a way of knowing following Fossil Finders instruction*
- *Students demonstrated more in-depth understandings about NOS as content matter following Fossil Finders instruction*
- *Students demonstrated content-matter learning about fossils and geology in class over the course of the instructional unit.*

As discussed above, student understandings of science are not limited to classroom learning experiences. They are shaped by life experiences, everyday and cultural understandings, which are partially shaped by media, as well as influenced by school science instruction. These understandings form the background knowledge that students may use to make sense of science in classroom situations. With classroom science instruction modeling the activities of science, Monica's students were able to experience science learning in a more authentic setting. These learning experiences provided students with new understandings about science. Within this learning environment, students thus had opportunities to negotiate prior understandings with new experience-based understandings about science framed within a context more authentic to science. Whether or not students fully accommodated these understandings remains beyond the scope of this research.

However, it is interesting to note that the degree to which students participated in the authentic investigation influenced their perceptions of science and scientific research. For example, students were involved in data collection but did not fully complete the data analysis aspects of the curriculum. Focus students also demonstrated informed understandings about the empirical nature of science and



processes of data collection in interviews. These same students, however, were not able to answer questions about the more abstract processes of science, such as what scientists later do with data. It is possible to infer that the scientific activities that students experienced thus shaped their understandings about the processes of science. Given the experiential nature of their learning, it is also likely that had students participated in working with the database they would also be able to describe how scientists use data.

Based on classroom learning experiences, students demonstrated tremendous growth related to geology-based content. For example, Raul, a student described in the results section, went from considering that sample rocks contained fossilized fish fins and fingers to correctly identifying fossils of the Devonian period. Moreover, he was able to make inferences using this knowledge about the environment of the past, to meet the overarching goal of the curriculum. In this way, Raul demonstrated content-matter learning related to fossilized organisms and the environmental conditions in which they lived. Other focus students also indicated growth in understandings related to the environment of the past. For example, all five focus students were able to identify that the local region was once covered by warm seas. These five students were also able to identify where the oldest fossils were in a diagram of an outcrop cross-section, as related to an understanding of sedimentation, or the deposit of new sediments, and superposition, how they stack on each other over time. While focus students demonstrated positive growth with respect to questions focused on fossils, students were not as successful in correctly responding to questions related to population characteristics and reading graphs. Again, student learning is indicative of classroom learning experiences in this case. Students in Monica's classroom did not cover content-matter related to population studies or to data analysis, which would include learning to read graphs.

Classroom learning experiences also influenced student understandings about NOS, as indicated by student results of the VNOS-E questions on the pre-post measure, and student interviews. The Results section includes examples of emerging understandings about NOS across student responses within the VNOS-E measure. These responses generally move from broad, mainstream views about science, to responses framed by the context of the Fossil Finders classroom activities. For example, though the pre-test responses do not make reference to geology or fossils, three of five focus students include science as the study of the earth, dinosaurs, or fossils in their post-test responses. These responses demonstrate student understandings about science framed by learning experiences and content in the classroom.

In interviews focusing on students' views of science, the five focus ELL students demonstrated emergent understandings of the tenets of NOS following the first instructional week of Fossil Finders activities. For example, students explained that scientists may be involved in various kinds of work, such as experimentation, data collection, and different kinds of research. Focus students also provided reflective comments, suggesting that their prior views had changed from considering science to be only about experimentation and chemicals. In this way, these students reveal emergent and more informed views about the diverse practices and fields of study that scientists may engage in. This includes considering science as a dynamic process, rather than either mainstream perceptions about science or science as an established set of facts learned in school.

Students also referenced classroom learning when explaining their views of the tentativeness and subjectivity of science, though these views were also intertwined with student understandings about science from their everyday and home lives. Raul and Bianca, for example, suggested that scientists may take guesses in relation to

fossils, as described in their interview responses in the results section. Further, with respect to the tentativeness of science, three of the focus students considered the possibility that scientists may not always be right. Paula positioned science as a way of knowing apart from public perception with her statement, “people don’t always think scientists are right.” This begs the question: who are these “people” to Paula and how does she consider them within or outside of this group? Raul also stated that “people don’t always agree with scientists” but he differentiates people from scientists based on having or not having scientific knowledge. In his interview response, as described above, he stated “some people aren’t right because they don’t know more than the scientist.” Raul thus positioned scientists as informed decision-makers who possibly have authority over other ways of knowing. Bianca demonstrated home-based views on science that held its authority in contention. She then described that her views were shaped by her father’s statement that scientists were not always right. These views illustrate where home-based views and skepticism about science, as illustrated by some of the students’ parents, may align with classroom learning experiences about the tentativeness of findings. When students raised examples about how scientists could disagree with one another based on identifying fossils, which were directly related to classroom learning, these views also transferred to support previously shaped notions about how scientists may not always be right. Student comments related to disagreements with respect to fossil identification demonstrate how classroom learning experiences may have in fact provided a context to consider how differences in opinion may occur in science.

Together, interview responses in relation to NOS reveal emerging understandings about science as a way of knowing. Understandings about the differing types of research scientists may be involved in, processes scientists may use, and opinions they may have, indicate more informed understandings about science

than students' initial broad explanations about science as having to do with experimentation and discovery. Students also developed understandings about scientists as agents of producing scientific knowledge. Nonetheless, some of the focus students positioned science and the work of scientists apart from the public. This distinction demonstrates an already-formed chasm between what students considered to be everyday knowledge versus scientific knowledge. While this is indicative of the divide between student worlds and science, it also reveals student understandings about science as a particular way of knowing and upholds the need for science instruction within the context of scientific activities.

Despite an instructional environment combining inquiry with IC and aspects of NOS, focus students did not yet develop understandings related to the socially and culturally embedded features of NOS. Though Monica's instructional approach did touch upon these features of NOS during the instructional unit (Table 10) and during the Tricky Tracks activity in particular (Table 13), students were not able to extend these classroom-based activities to commenting on how culturally based practices may influence science. It is possible that classroom instruction did not emphasize these points clearly enough. For example, the instructional unit did not include activities to consider how individuals with other cultural values or scientists from other countries or would comment on fossils found in their region. Given the experiential nature of student learning in science and the gap in student understandings about this aspect of NOS, an additional curricular activity may need to be included in the Fossil Finders unit.

However, another important consideration is students' views on cultural difference and their perspectives on how culture may be influenced from a developmental perspective. It may be unlikely for students at the 5<sup>th</sup> grade level to consider culture and the cultural aspects of science from a metareflective standpoint

(Kuhn, 1999). In other words, though students may have experienced both culture and IC practice, they do not yet have the language to explain these experiences as cultural interactions. Student responses to interview questions and other assessment measures may not currently demonstrate complete understandings about NOS, however emergent views may shape future understandings about science. This may be likened to learning progressions with respect to NOS content-matter. Though there is no literature to refer to for considering learning progressions in NOS, it can be assumed that an understanding that science is subjective will prepare students to later understand the cultural differences in science across the places where it is practiced.

Student learning is reflective of the classroom teaching environment and activities that students engaged in during the course of the Fossil Finders unit. Evidence of what students learned and contrarily did not learn with respect to content-matter, NOS, and understandings about inquiry uphold the situated aspects of scientific knowledge and practice. The classroom learning environment was designed to model the activities, context, and culture of science through the Fossil Finders instructional unit. Students demonstrated learning the science subject-matter and aspects of NOS that were emphasized during instruction. Though students did not demonstrate highly informed understandings of content-matter and NOS, they may have exhibited age-level appropriate understandings for an initial introduction to inquiry, geological content, and learning about NOS. For example, students in Monica's classroom demonstrated meeting the objectives for learning progressions associated with geological content-matter and understandings about evolution (Catley et al., 2005). These understandings at the 5th grade level may provide an experience-based foundation for future learning (Bransford & Schwartz, 1999). Further theoretical work and research may be necessary to consider the preparation for future learning and learning progressions associated with understandings about NOS. For

example, students within Monica's classroom demonstrated understandings of scientific knowledge as being subjective. However, they did not indicate understandings about how science may be influenced by the culture where it is practiced. It would be interesting to consider whether an understanding about the subjectivity of science would in fact serve to inform understandings about how science may be culturally influenced, dependant on where it is practiced.

Because research questions focused on student learning in relation to content-matter and understandings about NOS, learning was measured only in this area. However, it can be assumed that other learning also occurred within the course of the instructional unit. For example, Monica's instructional adaptations related to literacy skills were integrated into instruction. Though research has been previously conducted with respect to inquiry and literacy learning (Lee & Fradd, 1996; Rosebery, Warren, & Conant, 1992; Stoddart, Pinal, Latzke & Canaday, 2000), investigating how an instructional approach combining inquiry with IC and explicit instruction in NOS may affect language learning for ELL students may be grounds for further research.

Future research may also consider how the various constructs of the combined instructional approach may have supported students in science content learning. While previous research had been conducted with respect to inquiry and IC (Lee & Luykx, 2006), as well as explicit instruction in NOS (Lederman, 2004), this study focused on bringing these three constructs together to create an innovative learning environment for diverse students. Thus, the research design used in this case study did not consider separating or recombining the constructs in various ways, such as combining inquiry with only explicit instruction in NOS or IC with only NOS. Because it is not possible to separate how components of the instructional approach may have supported student learning in the context of this study, or measure how

students responded to IC, a follow-up study focused on these aspects would illuminate understandings with respect to how the focus constructs and their features may support student learning when combined in different ways. For example, if a teacher may not be well-versed in students' primary or home-based languages, what other aspects of IC may he or she emphasize to compensate? Further, if a teacher has perhaps never experienced conducting a scientific research study, how can learning about NOS better support his or her in using an inquiry-based approach? These understandings may provide practical guidance applicable to other classroom teachers working with diverse students.

*Summary: Understanding Student Experiences in Monica's Classroom*

This study cannot claim to fully understand students' science learning experiences in the context of this one classroom. However, the fact that these urban middle-school students from underrepresented backgrounds indicated positive learning experiences and interest in scientific careers serves to counter research on similar student groups indicating negative attitudes about science and their potential futures in scientific careers (Zacharia & Calabrese Barton, 2004). Most findings in this section are based on researcher-directed questions and responses to previously developed assessment measures, which may in turn direct and influence student responses. Nonetheless, students provide important information with respect to influences on students' perceptions about science and how these views may shift in response to their experiences within an instructional environment combining inquiry, IC, and explicit instruction in NOS. This involves negotiating mainstream, everyday, and cultural views on science with components of scientific culture as framed by the implementation of an authentic investigation in their classroom. For example, students commented on how science was different from what they thought it was and

demonstrated more informed understandings about NOS following participation in inquiry. Because bringing an authentic investigation into a classroom space combines the space of school, scientific practice, and student knowledge, it also merges the practices of school, scientific, and students' communities. The intersections between these CoPs also form a space for cultural negotiation; that of the practices and ways of knowing across these communities, which in turn frame the content within them.

### ***Emergent Findings beyond the Scope of Research Questions***

Most emergent findings address student experiences in the classroom and are discussed in the section above. These findings uphold claims set forth by other findings related to the original research questions and sub-questions. This section considers the emergent findings that stem beyond research questions and consider students experiences in combination with the instructional approach used in Monica's classroom (Table 22). These findings have important implications in considering the

**Table 22. Emergent Findings from Classroom Observations**

	<b><i>Emergent Findings</i></b>	<b><i>Description</i></b>
1	Student engagement in learning was affected by the type of instructional approach used by the teacher	Students demonstrated greater amounts of engagement and motivation to learn when interacting with fossils in small group-work settings than during large-group instruction.
2	Student scientific authority was influenced by the structural constraints of the classroom as related to other school programs	Students with lower levels of ELP received specialized language instruction and had less class time devoted to learning science; students with higher levels of ELP were designated as Fossil Finders leaders demonstrated greater amounts of confidence and scientific authority than other students.
3	Story-telling and writing created a space for cultural exchange between science, everyday ways of knowing, and the imaginary	Students bridged between everyday understandings, science, and the imaginary through story-telling and story writing. The scientist used a story-telling approach when visiting and thus contributed to this genre of science learning.



instructional approach used in this classroom and the related learning experiences of students and are discussed in more detail below.

#### *Student Engagement as Related to the Instructional Approach Used*

The first of the emergent findings has to do with combining Monica's instructional approach and student experiences over the course of the unit. Classroom observations and video data indicated differing levels of student engagement in learning, through questioning and body language. These findings point to students being more engaged in learning activities during student-centered instruction. This has to do with constructivism-based learning and a paradigm of inquiry and aligns with the literature suggesting that students are motivated to participate in learning through problem-based approaches (Wilkerson & Feletti, 1989). If motivated to participate, there is a higher probability for learning to be occurring. This corresponds with the ultimate goal of engaging underrepresented students in science learning.

#### *Specialized Language Instruction and its impacts on Scientific Authority and the Classroom Community*

Classroom observations led to the second emergent finding combining classroom and student experiences, which relates to the impacts of specialized English language instruction for ELL students on science learning and the classroom setting. While considerations for specialized language instruction remained outside of the scope of the original research design, they nonetheless impacted results. As described above, students with lower English language proficiency (ELP) levels were removed from their classrooms to attend specialized language instruction sessions. Because these sessions were scheduled during science sessions, the time that students with lower levels of ELP had for science learning was effectively reduced. Meanwhile, students with higher levels of ELP spent more time observing fossils and interacting

with their teacher surrounding science-based concepts. These students were also designated as the Fossil Finders Leaders with the task of sharing what they learned and assignments with peers upon their return to class. Though the sharing of scientific authority is a feature of IC, it seemed to apply to the Fossil Finders the most. Monica enabled students with higher levels of ELP to have scientific and instructional authority over their peers.

Though this student differentiation was a result of implementing school-based language programs to meet district requirements, it resulted in fostering greater amounts of confidence in science and scientific authority for students with higher ELP levels. For example, it was evident that the Fossil Finders Leaders raised their hands to answer questions more often than other students in the classroom. Consequently, a shaped the classroom community where some students were held more knowledgeable than others was formed. Additionally, it is not known to what extent Fossil Finders leaders actually transferred all aspects of Monica's instruction to the students returning from specialized language learning lessons as they were assigned.

While Monica engaged her students in science learning through the use of innovative instructional approaches, the structural constraints of her school impacted the instructional delivery of the curriculum and the classroom community and district. On the one hand, ELL students were receiving instruction to develop their language skills. On the other hand, this specialized instruction came at the cost of greater instructional time learning science. Educational researchers caution against specialized language instruction for students, apart from content-matter instruction, especially for students at the high school level. Valdes (2001) argues the result of specialized language instruction is that "students are often lost to the world of education. Whatever interest they might have had for subjects they had studied before they arrived here, must be put on an indefinite hold. The possibility of continuing to grow

intellectually must be deferred until such time as they are considered to be able to handle English” (Valdes, 2001, p.14). While Valdes’ research pertains to high school students, it is also applicable to middle school students in the case of Monica’s classroom. Researchers nonetheless point to the language and content-area learning that occurs for ELL students through participation inquiry languages (Rosebery et al., 1992; Stoddart et al., 2000, Warren et al., 2001).

### *Literacy as a Space for Cultural Exchange*

Research questions focused on how students bridge between everyday day ways of knowing and science through the space of inquiry and a combined instructional approach. Classroom observations, however, pointed to literacy-based activities as a platform for cultural exchange. This space of cultural exchange was inclusive of bringing science together with everyday ways of knowing, as well as the imaginary worlds of students.

As described in the Results section, the act of story-reading served as a regular part of classroom instruction. To this end, Monica would find various fiction and non-fiction texts to share with students as a part of instruction. For example, she supplemented the curriculum unit with images of dinosaurs as the students discussed what environment the dinosaur of the Tricky Tracks stories may have lived in. Her instructional approach aligns with providing linguistic scaffolding to students with differing levels of ELP. Showing illustrations as a part of instruction assisted students in assigning visual imagery to newly introduced vocabulary terms. Monica also embedded other forms of linguistic scaffolding into story-telling. Toward the end of the curriculum unit, Monica read a story about a young boy on a fossil dig out-loud to the class. While reading this story, she would pause and ask students to make predictions related to what would happen next. This literacy strategy encouraged

students to be active listeners and to draw the next series of possible events based on their everyday knowledge and prior understandings from the text. Further, as described in the results section, the visiting scientist used a story-telling narrative approach to tell students about her own life and experiences as a scientist. During this time, students interacted with the scientist by asking her questions about what it was like to be a scientist and how scientists went about doing their work. The context of story-telling thus played a large role in shaping the delivery of science in this particular classroom.

Monica also encouraged students to identify explicitly the relationship between texts they read to their everyday lives and other places by way of *text-to-text*, *text-to-world*, and *text-to-self* connections. In this way, Monica asked students to identify what a text and what it relates to, and conversely, what it does not. Monica also made literacy connections explicit to students and pointed out how scientific content may fit within their schemas of understanding. For example, students connected images of fossils within text to their classroom experiences of looking at fossils. Though books and other reading materials may have reflected the cultural attributes of science or other ways of knowing by how they were structured (i.e. a science textbook), Monica presented a tool for analyzing cultural difference between the medium and its content.

In many ways, making relationships between texts explicitly models what this study hoped to find with respect to IC in science instruction. Monica illustrates a way in which framing between different ways of knowing may occur through literacy practices. Monica, in essence, instructed students to actively make explicit linkages between literary pieces and their everyday lives, whereas this study focused on the implicit connections that students may make between everyday and cultural ways of knowing and science through a combined instructional approach that makes science explicit. With the assumption of the broad applicability of science, students may be

able to identify ways in which they are able to use it across different settings similarly to the connections between texts. This would include identifying what science is, and conversely, what it is not.

As described in the results section, students also wrote stories about the Tricky Tracks scenario. In this way Monica integrated English language arts requirements into science instruction. Perhaps more importantly, she framed this writing activity in terms of NOS. In writing stories, students needed to provide examples using evidence, or the tracks themselves, and make inferences about what happened based on these tracks. Moreover, Monica encouraged students to apply other features of NOS in writing their stories. For example, Monica instructed students to use their imaginations with the rationale that scientists use their imaginations. Through the use of their imaginations, students developed stories that combined scientific knowledge and explanations with everyday experiences and understandings. Interestingly, Monica did not check for the scientific accuracy of students' stories, though science content-matter knowledge was expressed through writing. Rather, the student story-writing activity provided students with platform to bring everyday, cultural, and scientific ideas together. Within this space, students were able make use of home and everyday languages in class, and with guidance their teacher, further their understandings, both imaginary and realistic, about science. In this way, Monica was able to bring together science instruction and English language arts instruction to meet school requirements and also further students' engagement in and interest and curiosity about science.

Interestingly, students largely did not recognize story-writing and telling as formal activities associated with science learning. Though writing is a formal and school-based activity that is one step removed from students' day-to-day life experiences, it combines school-based science learning with something other than

regular school practices. Monica provided a space for science instruction to be partially driven by and derived from student experiences in the space of stories. This instructional approach aligns with research focused how science instruction may stem from students' day to day life experiences with respect to rethinking scientific literacy (Roth & Calabrese Barton, 2004). Monica's literacy-based instructional approach differed from regular school-based practices in that it created a platform for cultural exchange between the imaginary, scientific, and personal spaces of students. In summary, while the classroom engaged in the practices of reading and writing, both scientific and everyday understandings were brought into the space and promoted cultural exchange. Thus, Monica's use of embedded literacy strategies served as a pathway toward increasing the accessibility of science, introducing new content-matter, and linking science learning to students' everyday understandings.

Emergent findings on writing as space for science learning, as well as findings related to the instructional approach used by the teacher and student responses and levels of ELP as related to scientific authority in the classroom do not directly address the research questions guiding this investigation. Rather, these findings begin to combine understandings about classroom contexts and student experiences within them, one of the greater purposes of this research. As such, they add to the findings discussed above and serve to inform and support the themes found across findings, which are described below.

### ***Themes across Findings***

The various findings discussed above with respect to theory piece together aspects of how an innovative instructional approach combining inquiry, IC, and explicit instruction in NOS was used in an urban middle-school classroom serving ELL and underrepresented students in the sciences and impacted students' science

learning experiences. These findings can be drawn together to put forward four unifying themes. The combined instructional approach used in Monica's classroom: 1) *increased the accessibility of science for students*, 2) *bridged between the spaces of*

**Table 23. Themes across Findings and Rationale**

	<b>Theme</b>	<b>Rationale</b>
I.	Combined instructional approach between inquiry, IC, and instruction in NOS increased accessibility of science content	Monica's instructional approach involved students in the activities of science through inquiry; Monica used explicit instruction in NOS to justify why students were doing particular things in science; Monica used IC to help connect students' everyday ways of knowing and language use to science learning.
II.	A combined instructional approach between inquiry, IC, and instruction in NOS drew on students' everyday ways of knowing and brought school and scientific communities together	Students used everyday ways of knowing to make sense of inquiry-based activities; Monica's implementation of features of inquiry and explicit instruction in NOS modeled scientific practice to a greater extent than traditional science instruction approaches; meeting a scientist had an impact on students' views on science and the work that scientists do
III.	A combined instructional approach between inquiry, IC, and instruction in NOS brought about opportunities for cultural exchange between everyday ways of knowing and science	A combined instructional approach created opportunities for cultural exchange and negotiating understandings about science through participation in inquiry-based activities; literacy activities also extended opportunities to combine everyday ways of knowing, scientific ways of knowing, and the imaginary in new ways
IV.	Student exhibited experiential learning related to the activities they participated in within the context of their classroom	Students demonstrated gains in content matter knowledge about fossils and understandings in the scientific processes data collection. These were the primary aspects of the Fossil Finders curriculum emphasized in the context of Monica's classroom.

*students, school and science, 3) supported cultural exchange as a part of science teaching and learning, and 4) provided students with learning opportunities that influenced their content-matter understandings and understandings about science.*

These themes illustrate the possibility for reshaping science education in urban school settings and the potential for innovative instructional approaches to positively affect student understandings, views, and interest in science.

Though Monica's instructional approach to implementing features of inquiry, IC, and instruction in NOS varied over the course of the Fossil Finders unit, science instruction in this classroom engaged students in the activities of science and reshaped their views about scientific practices.

The first theme emerging from across findings includes that the combined instructional approach helped increase the accessibility of science content for underrepresented and ELL students. This entails included increased access to the following: 1) scientific ways of knowing through participation in scientific activities, 2) scientific culture through explicit instruction in NOS explaining the rationale for scientific activities, and 3) scientific language through adopting language support strategies from IC. Findings from above illustrate how Monica's instructional approach involved her students in the activities of science through inquiry. By engaging her students in an authentic investigation, Monica also increased her students' access to learning about scientific activities and practices. This approach aligns with other research considering the accessibility of authentic science to students (Lee & Songer, 2003). Introducing this approach to the classroom science instruction provided Monica's students with a context more congruent to scientific CoPs than traditional instructional approaches. Monica also exhibited using explicit instruction in NOS and features of this construct to justify the inquiry-based activities and frame what students were doing. Monica made it clear to her students that they were



involved in actual scientific work and observing actual samples. In this way, students were not only a part of the processes of science but also scientific ways of knowing as a whole. Thus, the activities of science were structured around something larger than the classroom or the school. The combined instructional approach also worked to link classroom learning to students' everyday ways of knowing and uses of language, thereby increasing the accessibility of science curriculum. This was seen through instructionally congruent practice and included the use of linguistic scaffolding and everyday languages in the classroom.

The second theme drawn from across findings includes that the combined instructional approach helped bridge between the spaces of students, school and science in Monica's classroom. Findings described above demonstrated how students used everyday ways of knowing to make sense of new approaches to science instruction and inquiry-based activities. Merging school-based settings with the scientific CoP through the context of an authentic investigation also expanded students' understandings of scientific work. This included participating in scientific activities, or inquiry, and also interacting with a scientist. In this way, the classroom science learning setting was more aligned with the scientific field. The combined instructional approach also created opportunities for students to bridge between everyday ways of knowing and school science. Students, for instance, made sense of scientific content-matter by relying on their everyday ways of knowing, as described above. The combined instructional approach thus bridged between the spaces of everyday ways of knowing, school-based science, and the scientific enterprise. This can be illustrated in how Monica implemented features of the NOS construct across various spaces of differing understandings to bring together everyday ways of knowing, school-based science, and scientific understandings. For example, with an explanation of how school-based activities modeled the work of scientists, Monica

provided students with a space to apply their prior knowledge and everyday ways of knowing and skills such as measuring, writing, and note-taking directly to the activities of science. Other examples included bridging between mainstream views about science and the actual work of scientists through discussions about what scientists do and the implementation of classroom-based activities, such as Tricky Tracks, to illustrate the features of NOS.

The third theme from across findings points to how a combined instructional approach created learning opportunities for students by reframing the classroom as a space for negotiating cultural differences between everyday ways of knowing and science, rather than solely a space for new content-matter learning. Monica's students entered her classroom with previous understandings about science, based on everyday and community ways of knowing. These understandings surfaced during school-based science instruction through IC instructional strategies. An NOS-based lens to frame science instruction positioned the activities of science within a paradigm and provided justification for scientific activities as specific to a way of knowing. Inquiry, combined with explicit instruction in NOS, repositioned the scientific field from an abstract space to a tangible one that that students could begin to experience in the classroom. With Monica framing the assumptions of science and how the field works through explicit instruction in NOS, students in her classroom began to demonstrate more informed views about science. This included mediating their preconceived notions about science, which were largely shaped by previous experiences including mainstream cultural views about science and scientists, with actual practice.

Monica also provided a space for science instruction to be partially driven by and derived from student experiences in the space of stories. This instructional approach aligns with research focused how science instruction may stem from students' day to day life experiences with respect to rethinking scientific literacy (Roth

& Calabrese Barton, 2004). Monica's literacy-based instructional approach differed from regular school-based practices in that it created a platform for cultural exchange between the imaginary, scientific, and personal spaces of students. In summary, while the classroom engaged in the practices of reading and writing, both scientific and everyday understandings were brought into the space and promoted cultural exchange. Thus, Monica's use of embedded literacy strategies served as a pathway toward increasing the accessibility of science, introducing new content-matter, and linking science learning to students' everyday understandings. In these ways, the combined instructional approach between inquiry, IC, and explicit instruction in NOS provided a space for students to engage in the activities of science and mediate between prior ways of knowing and explain scientific ways of knowing. This negotiation between ways of knowing occurred based on classroom-based science learning activities contextualized by inquiry.

The fourth theme that is upheld across findings is that students demonstrated content-matter learning related to the activities they participated in within the context of their classroom. This included knowledge growth and shifts in understandings related to fossils and the scientific processes data collection. As these were the primary aspects of the Fossil Finders curriculum emphasized in the context of Monica's classroom, it is possible to conclude that student learning greatly influenced by their classroom experiences. These findings point to the importance of better framing school-based science instruction and the potential for students to gain better understandings of science in their classrooms.

Together, themes from across this research make the case for using an instructional approach in science that recognizes science as a cultural way of knowing and provides opportunities for students to mediate between their everyday cultural ways of knowing and science. This, as a project, challenges notions of traditional

science instruction, where students' everyday ways of knowing may not be recognized in the learning process and science is not positioned as a particular way of knowing that can be accommodated rather than assimilated into. However, a fine line exists between traditional instruction in science and inquiry-based instructional practices in term of involving students in the culture of science. By engaging students in scientific activities through inquiry, students also undergo a process of enculturation into science. This research makes a point of departure from other work focused on engaging underrepresented students in inquiry by considering how inquiry-based instruction can frame scientific ways of knowing through instruction in NOS. In this case, student learning is focused on demystifying science in combination with learning about scientific content-matter and processes. Learning science from this perspective repositions the scientific content-matter within the realm science as a particular way of knowing, with its own possibilities and limitations. Classroom science learning thus considers the features of scientific knowledge; how it remains tentative, subjective, and contested within the field, rather than accepted as factual information. This is not the case in most school-based science learning settings serving students who are underrepresented in the sciences. As such, this research falls into the paradigm of rethinking *how* we teach science and position it as a field to underrepresented students in school-based settings rather than challenging notions of science itself. In this way, this work takes a pragmatic stance of considering how to make small incremental shifts toward bettering science instruction for underrepresented students within the space of preexisting conditions, or generally traditional school-based science learning environments. It does not challenge power dynamics associated with science with respect to other ways of knowing, as do radical reform-based considerations (Stanley & Brickhouse, 1994). Nonetheless, with science instruction that frames scientific knowledge within the space of its own paradigm, students may begin to recognize and

differentiate between scientific ways of knowing and other ways of knowing. It is my hope that this approach will in turn better position underrepresented students to: 1) recognize science as a way of knowing, and 2) negotiate between cultural ways of knowing and science, and 3) challenge science through the knowledge of what it is as a field and its possibilities and limitations. Instructional approaches in science that demystify science may in turn, prepare underrepresented students for further studies in science, science-related positions, and further projects focused on reforming science as a field in general.

## CONCLUSION

Too many students from underrepresented backgrounds in the sciences remain marginalized as a result of the lack of authentic learning experiences in their classrooms that would provide students with opportunities to experience scientific activities, contexts, and cultures. This dissertation presents an argument for transforming approaches to science education for underrepresented students by considering the opportunities for science learning at the intersection of scientific culture and students' everyday ways of knowing. If school science instruction is presented in a way that is authentic to the practices of science and accessible to students, linguistically and on a deeper level across epistemic divides, then barriers to the success of these students may be diminished. Though educational reforms focused on inquiry present an alternative to traditional didactic methods of science instruction, findings from this research make the case for merging inquiry with multicultural instructionally congruent teaching strategies. In particular, this includes framing and extending explicit instruction in NOS as a multicultural approach.

Inquiry holds promise in reaching student groups that have remained underrepresented in the sciences through the avenues of traditional schooling. However, inquiry, without consideration of students' cultural understandings and the cultural aspects of science may not be sufficient to improve diverse student groups' understandings about science. Multicultural strategies in science, such as IC, provide a pathway to bolster inquiry with instructional approaches that draw on students' everyday ways of knowing. However, explicit instruction in NOS may be the vehicle to help demystify science for underrepresented students. Learning science from this perspective repositions the scientific content-matter within the realm science as a particular way of knowing, with its own possibilities and limitations. Inquiry

combined with IC and explicit instruction in NOS thus presents a theoretical model for an instructional approach to facilitate a process of navigating and negotiating the culturally sensitive spaces of students in science education. Inquiry and IC, and inquiry and explicit instruction in NOS, have been grouped together as instructional approaches previously in the literature; however, all three have not yet been merged in theory or practice. The Fossil Finders project, an authentic scientific investigation brought into an urban classroom serving underrepresented students, presented an opportunity to explore how these instructional approaches could be combined.

This research thus focuses on the classroom space, merging the practices, activities, and knowledge of school, students, and scientists, as its unit of analysis, with Monica's implementation of the Fossil Finders curriculum as its focal point. Monica, the focus teacher of this study, presented a unique case of a novice 5<sup>th</sup> grade science teacher who was able to, in many ways, implement an instructional approach combining inquiry with IC and explicit instruction in NOS in her science teaching. Selecting Monica is significant in that she is representative of many teachers who have multi-subject credentials for elementary and middle school instruction. Though she was interested in teaching science, she had received little formal academic preparation to do so other than through various professional development (PD) experiences. Monica thus demonstrates the potential for other elementary and middle school educators to successfully bring effective science curriculum materials into their classrooms by attending rigorous and targeted PD programs. This finding is particularly relevant in a climate with a heavy emphasis on mathematics and reading instruction by way of standardized testing in these areas. Introducing science curriculum to underrepresented students in elementary and middle school levels may prepare these students with a foundation for future success in science learning. Monica's classroom provides evidence that it is possible for teachers to carry out

innovative approaches to science instruction at the elementary and middle school levels

Evidence suggests that Monica implemented the inquiry-based instructional materials she had first experienced as a learner in a PD program. In the PD, she participated in elements of an authentic science investigation through data collection and preliminary analysis. Further, she was beginning to use inquiry in her classroom as it was modeled in the PD program. It is significant that though she had limited experience in science and conducting scientific research, she translated her experiences in the PD program and involved her students in an authentic scientific investigation. Her instruction included guiding her students through some of the processes of data collection and analysis. Monica's instructional approach also took a point of departure from her regular classroom instruction, as a result of introducing an authentic science investigation in her classroom. Whereas her students equated science learning as "reading from a book" and "listening to your teacher" prior to the investigation, it is evident that in the context of the authentic investigation, Monica began to adopt more student-centered and constructivism-oriented instructional approaches more congruent with inquiry. Consequently, students in Monica's classroom were engaged in all five essential features of inquiry in the context of the investigation: engaging in a scientifically oriented question, using evidence to respond to questions and constructing explanations, connecting explanations to scientific knowledge, and communicating and justifying findings (NRC, 2000). This is significant in considering the potential for urban elementary and middle school classrooms to provide authentic science learning opportunities for underrepresented students.

Results also indicate that Monica successfully integrated IC strategies with inquiry-based science instruction in her classroom. Though Monica's background and



instructional setting in a dual-language classroom facilitated the use of students' home and everyday languages and references from cultural understandings as a part of teaching, she provides insight into how literacy development may be integrated into inquiry-based science instruction. Monica's instructional focus on literacy skills and inquiry may have resulted in greater learning opportunities for students. Literacy activities provided a space for students to bring together scientific understandings with everyday understandings and the imaginary. Students were thus supported in bridging science instruction with everyday understandings. Monica's use of linguistic scaffolding also served to increase the accessibility of science instruction for students with differing levels of ELP. These forms of linguistic scaffolding may serve to benefit all students, to whom science is a second language (Lemke, 1990). Further, a student-centered instructional approach through inquiry contributed to the sharing of scientific authority of students and their participation in the activities of science. This student positioning not only validated student contributions to the classroom, but also framed students as active contributors in the construction of scientific knowledge. In these ways, Monica's use of instructional congruency increased the accessibility of science instruction and reinforced aspects of inquiry.

The authentic nature of the investigation created opportunities for embedding features of NOS into classroom instruction, which formed the cornerstone of this investigation. Explicit instruction in NOS framed the relevancy of the activities involved in the investigation as a part of science, and through participation, students as active agents of knowledge production. In this way, they experienced aspects of NOS associated with scientific processes, such as having tentative findings, communicating and justifying their results, and connecting their explanations to age-level appropriate scientific understandings. Further, through referencing aspects of NOS, Monica was able to demystify the purposes for particular activities associated with the

investigation in her classroom. For example, she assigned students to take accurate notes, using the rationale that scientists keep accurate notes. This statement emphasizes the empirical features of NOS, through which Monica framed what scientists do. Foundational learning related to features of NOS may prepare students for future learning in science with the understanding that scientific content-matter does not stand apart from the processes in which it was derived. Students in Monica's classroom were introduced to the empirical and interpretive aspects of science through making observations and inferences (NAS, 1998). Further research is needed to determine whether or not understandings about the NOS aspect of subjectivity in science may provide a foundation for understanding differences in science across cultures. This is a key component for science instruction for underrepresented groups (Lipka et al., 1998).

A positive finding of this study is that underrepresented and ELL students were engaged in science learning through Monica's instructional approach and demonstrated gains in content-matter knowledge and more developed understandings about NOS. For example, certain students who had initially identified fossilized samples from the Devonian period as "fingers and fish fins" (which is scientifically inaccurate), later accurately identified these fossilized organisms as cephalopods and brachiopods. Students thus demonstrated geological and paleontological content matter learning. Students further demonstrated extending these understandings to making interpretations about the geology of the past and they made the inference that their local environment was once covered by sea water, based on finding fossilized seashells in the sample. These learning gains create a compelling case for the use of inquiry with underrepresented and ELL students. Findings related to learning gains align with literature on targeted age-level appropriate understandings about evolutionary concepts (Catley et al., 2005) and other research on inquiry

demonstrating gains in learning for underrepresented students in science (Marx, et al., 2004). They also align with research demonstrating gains for low achieving students with low SES levels through inquiry (Cuevas et al., 2005).

Perhaps one of the most important contributions of this study, however, is the change in student understandings about what science is, as a result of the instructional approach used in the classroom. After participating in an authentic investigation and interacting with a scientist, students in this classroom demonstrated more sophisticated understandings about aspects of scientific inquiry and NOS. Rather than seeing science as solely subject-matter, students were beginning to see science as a process and as a way of knowing. These changes are well illustrated in a comment made by Alyssa, one of the focus students, when she stated, “before we started working on fossils, I thought science was reading out of a book.” Alyssa later described science as “when you study about the earth and do expirimets, try to figer out things, to observe, to anylise and to infer [sic].” Though students did not engage in open, complete and independent inquiry nor demonstrate full understandings about inquiry and NOS through the context of this study, they were provided with a space for experiencing and negotiating understandings about science through activities authentic to science. That these students demonstrated learning gains about both science content and the processes of scientific inquiry and NOS makes the case for expanding the use of this instructional approach with other groups of students from underrepresented backgrounds.

Bringing an authentic investigation into the classroom space combined school activities with scientific practice and students’ prior understandings about science in this classroom. This approach thus merged aspects of school, scientific, and student communities. The intersections between these communities and their practices formed a space for cultural negotiation; that of scientific practice and everyday ways of

knowing. In this way, the instructional approach used in this classroom introduced students to aspects of scientific communities in school, rather than solely communities of schooled adults (Lave & Wenger, 1991). As described above, the merging of these communities provided students with opportunities to negotiate understandings about science.

Findings suggest that the key aspects of making cultural negotiation possible was demystifying the culture of science through explicit instruction in NOS and bringing students' everyday and cultural ways of knowing into the classroom through IC. This included considering mainstream understandings about science, which shaped students' perceptions about science content and scientific research in this study. These mainstream understandings painted a picture of misconceptions about scientific research and the work of scientists. Recognition of the cultural influences that shape understandings about science, including influences from mainstream culture, has implications for instructional approaches in school science. This includes the importance of school science to be taught within the context of scientific culture through inquiry. Because traditional instruction in science does little to represent the authentic context of scientific work, student learning about science in traditional classrooms may continue to reflect and reinforce the misconceptions brought about by mainstream culture (Driver, Squires, Rushworth, & Wood-Robinson, 1993).

This study also suggests that for educators to implement this instructional approach, substantial and prolonged PD and support is needed. Inquiry is a challenging instructional approach to implement. Nonetheless, Monica demonstrated that it is possible to implement basic features of it in a 5<sup>th</sup> grade classroom following participation in PD. Additional PD may further enhance the instructional enactment of inquiry in her classroom. Monica's instructional approach also may hinge on her support and experiences in providing linguistic support to her students; other teachers

may require PD in this area to implement IC instructional strategies. Further, PD related to the cultural aspects of science is paramount to the implementation of an instructional approach combining the three guiding constructs of this study. This includes greater emphasis on science across different ways of knowing and the features of NOS, inclusive of the socially and culturally embedded nature of scientific knowledge.

This study provides evidence for making the case that a combined instructional approach across inquiry, IC, and explicit instruction in NOS: 1) made science accessible to students to a certain extent, 2) bridged between the spaces of students, school and science, 3) supported cultural exchange as a part of science teaching and learning, and 4) provided students with learning opportunities that influenced their content-matter understandings and understandings about science. These themes support the instructional model proposed in this study and demonstrate the feasibility of reshaping instructional approaches to science education in urban school settings. Findings also demonstrate the potential for innovative instructional approaches to enhance student understandings, views, and interest in science. Further research may consider larger-scaled studies focused on student learning and instruction in other science subject-matter using the same approach.

This research thus provides grounds for reconsidering use of instructional strategies that focus primarily on standardized test preparation as a means for closing the achievement gap in science education. In particular, this research considers ways to rethink *how* we can best teach science to underrepresented students and what kinds of instructional approaches may engage students in the authentic activities of science and science learning. This includes the following considerations: facilitating the negotiation of understandings across everyday and scientific ways of knowing; addressing the cultural backgrounds of students with components of science;

increasing the relevancy of science instruction to all students; and providing greater access to scientific content and processes. Combining inquiry, IC, and explicit instruction in NOS provides an instructional approach to frame the field of science and engage underrepresented students in science learning, an alternative approach to closing the gap in student achievement in science. With small incremental shifts toward fostering better science learning experiences for underrepresented students in classroom spaces through participation in culturally sensitive authentic investigations, this research strives to contribute to the academic success of student groups currently challenged by the cultural aspects of science. That these students may be later participating in higher education settings focused on scientific research, taking on science-related positions and projects focused on reforming science as a field in general, is the hopeful outcome of this research.

## APPENDIX A

### IRB Project Amendment Form and Approval

Revision: 11/09/2007

#### REQUEST TO AMEND A PREVIOUSLY-APPROVED PROJECT

#### CORNELL UNIVERSITY Institutional Review Board – Human Participants

- All information must be typed. Handwritten applications are not accepted by the IRB.
- Attach a copy of all amended/final instruments, *highlighting the changes* from the previously reviewed and approved instruments.
- Submit this form, with appropriate signatures and necessary attachments, to: IRB - ORIA, 395 Pine Tree Road, Suite 320, Ithaca NY 14850

*Please click in shaded fields to enter information*

#### Project Identification:

Title of Research Project (*use same title under which project was approved*)

Fossil Finders: Using Fossils to Teach about Evolution, Inquiry, and Nature of Science

Protocol ID# (found on latest approval letter): 07-08-024

Investigator's Name: Barbara Crawford

Campus Address: 400 Kennedy Hall, Ithaca NY 14853

Investigator's Signature: \_\_\_\_\_

Signature of faculty member supervising project (if applicable): \_\_\_\_\_

Date of request: 8/26/2008

Anticipated End Date of Project: 12/20/2008

#### Information on Amendments

1. What type(s) of amendment(s) are you requesting? Please describe in detail.

I am requesting an amendment approving classroom research related to the Fossil Finders project. This research will make use of the same data gathered through the Fossil Finders. However, this research will also include the use of the Framework for Instructional Congruency (Luykx & Lee, 2007) in conducting a content analysis of classroom instruction. Moreover, this research proposes the use of focus group interview with students and interviews along the lines of the Inquiry Elicitation Protocol (Cuevas et al., 2005), to gather data on student understandings of nature of science and inquiry.

2. Briefly describe the reason(s) you are making amendment(s) to the study.

This proposed dissertation research focuses on Latino and English language learning students involved in the Fossil Finders project in their science classrooms. The proposed changes to the study provide include interviewing students and student focus groups in order to obtain greater detailed information on students' views of science and nature of science. An interview approach will provide greater in-depth detail representing student views on science than other forms of data collection, such as pre-post tests, surveys, or observations.

Changes also include using a framework to analyze cultural and linguistic differences in science instruction. Purposes for using the Inquiry Elicitation Protocol and the Framework for Instructional Congruency are described in further detail here:

#### 1. Why the Inquiry Elicitation Protocol?

The Luykx and Lee (2007) framework for instructional congruency offers a classroom observation tool that combines considerations for science learning and sociocultural difference. Though the framework is structured for large-scale observation studies, it provides a tool from which to quantify observations of

culturally congruent science teaching practices. These include a teacher's use of: 1) scientific authority, 2) diversity of cultural experiences and materials, 3) students' home language in regular (non-bilingual) classrooms, and 4) linguistic scaffolding to enhance meaning, during classroom instruction.

**2. Why the Framework for Instructional Congruency?**

Cuevas et al. (2005) developed an elicitation protocol and rubric to evaluate diverse elementary school students' understanding of inquiry. This instrument probes students on their understandings of scientific investigation based on a scenario. Other research supports this approach for evaluating students' understandings of inquiry (Chinn & Malhotra, 2002). One of the assumptions of this research is that students will have differing levels of English language proficiency. This protocol and its associated evaluation rubric account for various levels of language proficiency in that student responses are open-ended and can be probed.

3. Are any of these changes the result of something that occurred during human participant interaction? Yes ☒ No

**If Yes, please describe the event(s):**

4. Are you submitting, for IRB approval, revisions of or new study interviews, questionnaires, study guides, or debriefing forms?

☒ Yes (please attach) ☐ No

5. Are you submitting, for IRB approval, final forms of study protocols that were reviewed in draft form?

Yes (please attach) ☒ No

6. Are you submitting, for IRB approval, a revised version of or a new informed consent document or procedure?

Yes (please attach) ☒ No

7. Are you submitting, for IRB approval, any other change in study procedures, such as design, designation of principal investigator, change in the recruitment techniques, etc.? Yes ☒ No

**If Yes, please describe those changes and attach documentation (as necessary).**



**NOTIFICATION OF AMENDMENT APPROVAL**

Protocol ID# 07-08-024

To: Barbara A. Crawford  
From: Susan R. Lewis, IRB Coordinator  
Date of approval: September 2, 2008  
Project(s): *Fossil Finders: Using Fossils to Teach about Evolution, Inquiry and Nature of Science*

I have reviewed the following amendment(s) to the above referenced project and find that your protocol remains "Exempt" with this modification:

**8-26-08 Amendment:** I am requesting an amendment approving classroom research related to the Fossil Finders project. This research will make use of the same data gathered through the Fossil Finders. However, this research will also include the use of the Framework for Instructional Congruency (Lyukx & Lee, 2007) in conducting a content analysis of classroom instruction. Moreover, this research proposes the use of focus group interviews with students and interviews along the lines of the Inquiry Elicitation Protocol (Cuevas et al., 2005), to gather data on student understandings of nature of science and inquiry.

If you requested modifications to a consent form(s):

- Use only the modified form for additional subject enrollment.
- Include on the form the date of this notification for the revised IRB approval date.

If you submitted revised/final versions of interview guides, questionnaires, or debriefing scripts, you have approval to use these materials immediately.

*All other study procedures/instruments are to remain unchanged from the original submission and IRB approval.*

## APPENDIX B

### Classroom Observation Notes and Video Guides

#### Fossil Finders Curriculum- Monica's Classroom, Fall 2008

<b>Date</b>	<b>Day</b>	<b>Title</b>	
9/30	1	MV1	Tricky Tracks
10/6	2	MV2	Dinosaurs
			Tricky Tracks Backwards
10/7	3	MV3	Vocabulary
			Fossil Exploration
10/20	X	MV4	Meal Worms and Measurements
10/24	X	MV5	Meal Worms and Measurements
10/28	X	MV6	Meal Worm Reports
11/17	4	MV7	Tricky Tracks Stories
11/24	5	MV8	Fossil Identification
		MV9	Small Group "Fossil Fever" Reading
			Tricky Tracks Stories
12/1	6	MV10	Fossil Finders Leaders Fossil Measurements
		MV11	Class Fossil Measurements
12/2	7	MV12	Fossil Finders Leaders Data Sheets
		MV13	"Fossil Fever" Read Aloud, Making inferences
			Tricky Tracks Stories, Text connections; self to text
12/3	8	MV14	Tricky Tracks Stories
12/8	9	MV15	Computer Modules
		MV16	Fossil Finders Website Comments
12/9	10	MV17	Ask A Scientist: PRI visit
		MV18	Fossil Finders Investigation
12/10	11	MV19	Fossil Finders Investigation Continued
12/12	12	MV20	Verifying Data
12/15	13	MV21	Data Review

#### **MV01\_TrickyTracks\_093008 (00:34:54; in clips)**

In this lesson, Monica introduces students to Tricky Tracks and asks them to take notes on what they think at the end of each segment and share out their thoughts. Monica asks students to pull out science notebooks (great strategy to journal with ELLs) and gives instructions to some student in Spanish. Students share their journal entries with me, where they consider tracks to be made by ducks, raccoons, squirrels, etc. Monica invites the class back to a large group and invites students to share out

their thoughts. She does not correct any of them (allows for multiplicity of answers) and probes students to explain why they are thinking what they state. In this space, she also discusses observations and inferences. Monica uses the example of snow and footprints that students might use to make an inference that someone walked by. Students sharing thoughts about what happened and from now on, associate the prints with dinosaurs (I am missing the moment where Monica introduces this connection). Students review vocabulary- carnivores, herbivores, omnivores. Students then consider scenarios—dinosaurs fighting, go home. Monica corrects student inference that dinosaurs “go home”- there is a food chain and the prints do not turn around.

#### **MV02\_FossilIntroTrickyTracks2\_100608 (1:07:40)**

In this lesson, Monica works with a smaller group of students, while others are drawn out of class for specialized instruction. Monica assigns these students to be Fossil Finders Leaders and will work through curriculum with them first. Then, these students will be teaching other students. Monica hands this group of students (8) fossils to observe and write notes about. There is a great NOS moment here (3:07) where Monica talks about the importance of accurate records for scientists. She remains open-ended about what students are seeing. Students believe they are seeing footprints, fish, etc. I interview students about what they are seeing during this section and ask them to identify whether they are making observations/inferences. The other students return and Monica uses the context of students looking at fossils to talk about the differences between observations and inferences (22:00). Students are fully engaged in making observations. Monica encourages student to come up with further questions. At (28:00) Monica reflects on what she is doing later that day and pulls a few books from shelves to illustrate what she is pointing out during instruction/using as a resource. Monica goes over a book with images of a pterodactyl at this point. At (31:38) Monica elicits student recollection of pre-historic animals and making connections between these organisms and animals alive today. When other students return (40:00), Monica uses Tricky Tracks backwards from Position 3 to 2 to 1 and asks students to describe what they think may have happened. Students work in groups, Monica uses Spanish with student to support learning, and Monica asks me to share what I think about Tricky Tracks with students. At (59:00) Monica discusses that scientists may have different perspectives/theories, which she also calls “stories” and refers back to the pre-test. Students share out what they think about the Tricky Tracks scenario.

#### **MV03\_FossilExploration\_100708 (37:17)**

Monica opens this lesson with a review of vocabulary related to inferences and observations. She reminds students to put the date on the top of the page and asks why scientists always do this. She adds that this helps them keep accurate records. Monica uses the Tricky Tracks KWL charts (I reformatted for her to include less vocabulary) and the first part of instruction. Students came up with ways to explain observations and inferences in their own words. Monica provides some ELL support during this portion of the lesson and refers back to what students did in Tricky Tracks. Students report out what they had in their notebooks. Students then move into groups

with their group leaders and Monica hands out fossils. Kids are smelling fossils, looking at them closely, and are excited. At (25:30) “Dame verlo”—[translation: Let me see it!] Students are very descriptive when I probe them about what they are seeing (I wonder if this is coming out in their writing as well). At (29:28) “Is this real?” At (30:09) student recognizes trilobite in Fossil Finders logo compared to the rock he was observing. From 30:37-32:00: a rich exchange in students describing what they are seeing and using of Spanish informally and with Monica. Interviewing students on what they are seeing—great clips from 32:45-36:00. A reflective clip of what Monica thinks about using an inquiry-based instructional approach (it’s so hard not to give answers...)

#### **MV04\_MetricSystemMealworms\_SelfRecording\_102008 (1:02:00)<sup>6</sup>**

There are two days of video recordings on this tape. It starts with a small group of students observing mealworm without knowing what they are. Monica reinforces that they are making inferences to guess what they are seeing. Students will be using mealworms to learn the metric system in preparation for the Fossil Finders unit. Monica explains that different things students will be doing to mealworms (tapping on desk, blowing at it, dripping water on it) are called “variables.” In large group instruction, Monica instructs students to compare things that measure larger and smaller than a mealworm. Ends at (31:42)

Next day of instruction begins with a recollection of what students did the previous day and making inferences based on what we saw (33:20). Also, an NOS moment that scientists have to keep accurate notes (33:38). Monica asks students to convert cm to mm and then asks how this lesson will connect to the Fossil Finders unit (37:09). Students respond with “observing and making inferences,” and that “will be using metric system to measure fossils.” At (40:00) students engaged in looking at mealworms. Monica uses context of mealworm to introduce story-writing (planning on having students write stories about Tricky Tracks later). At (51:14) Monica instructions to look at color. At (55:29), Ricardo notices that his mealworm is different than the rest. Monica talks a lot about measurements; students are measuring items around the classroom and engaged in activity.

#### **MV05\_MealwormObservations\_SelfRecording\_102808 (1:01:11)<sup>7</sup>**

In this lesson, Monica uses mealworms to set the context to teach concepts related to the metric system. The clip opens with students using a computer to look up information related to mealworms and figuring out what the word “molting” means. It also demonstrates students recollecting how to convert metric cm to mm measurements, making measurements, and presenting measurements larger and

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<sup>6</sup> This video was taken by Monica, with the camera set up in the back of the classroom. Data from this video was not analyzed for this dissertation work as the curriculum remained outside of the scope of the Fossil Finders curriculum. It is included in this video overview to contextualize instruction surrounding the Fossil Finders investigation.

<sup>7</sup> This video was taken by Monica, with the camera set up in the back of the classroom. Data from this video was not analyzed for this dissertation work as the curriculum remained outside of the scope of the Fossil Finders curriculum. It is included in this video overview to contextualize instruction surrounding the Fossil Finders investigation.

smaller than their mealworms. Monica then opens the classroom space for student observations of their mealworms. Students will be writing stories about their mealworms. Monica interviews some students to talk more about what they are seeing. Very open-ended lesson and students engaged in making observations in small groups. “Juan, make sure you have today’s date... la fecha.” Monica concludes with intent to read a book about mealworms.

#### **MV06\_MealWormStory\_SelfRecording\_102808 (21:23)<sup>8</sup>**

Uses mealworms as a context for story-writing and learning literacy skills. Who is author? Who is illustrator? When reading book, Monica asks for predictions. From this page, what can you predict? Book reading introduces new vocabulary along the way and is framed as a conversation along the way, making references to what students are seeing. At (9:57) students are making connections from what they are learning to previous experiences and home experiences. Sharing out. At (10:51) does it look like a cucarracha. Juan (10:55) “En Puerto Rico yo coji a esos... se llaman caculos... por la noche salen muchos.” Monica responds in Spanish – is it a lightning bug? Juan says no. Monica repeats what he said in English. Beetles like to eat grain and cereal is made of grain... making connections to everyday life. The beetle lays her eggs... she met Mr. Beetle and they made babies. At (15:21) life cycle includes death, but procreation is a part of life. Reviews new vocabulary. What comes out of the egg, then it becomes a ... do you remember what they were called in English? Change is called metamorphosis—this is the last part of the mealworm book.

#### **MV07\_TrickyTracksStories\_111708 (1:00:08)**

Monica made adaptations to the Tricky Tracks lesson to include it as a part of her writing curriculum. In this lesson, Monica reintroduces the concept that scientists may have different understandings of the same scenario and invites students to interpret the Tricky Tracks as paleontologists (though not limited to this) and write their own version of the story. Monica goes over the components of story-writing and instructs students to come up with ideas about the setting in which Tricky Tracks may have occurred. Much of the classroom went on to be imaginative, with not much guidance and structure, other than reference to illustration books and posters about dinosaurs. There was no mention of dinosaurs or mention of uniformitarianism in that prints may occur under similar conditions. Perhaps this will come out tomorrow. Students worked individually on writing their stories. Monica made great use of graphic organizers in doing so and integrated literacy and language learning into this lesson. Students presenting and commenting on each others’ work is a mainstay in this classroom; though commenting remains at the level of students telling each other things they liked about their work.

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<sup>8</sup> This video was taken by Monica, with the camera set up in the back of the classroom. Data from this video was not analyzed for this dissertation work as the curriculum remained outside of the scope of the Fossil Finders curriculum. It is included in this video overview to contextualize instruction surrounding the Fossil Finders investigation.

### **MV08-MV09\_112408\_FossilObservations**

In today's lesson (~1.5 hrs total), Monica worked with a small group of students first and pulled out a "practice set" of fossils-- fossils that she collected herself this summer at a few different sites. She had students observe rocks, draw them in their notebooks, and try to identify fossils using PRI sheet (this was the first day they had the ID sheet). Students were instructed to add title and date to the top of their notebook entries. I asked a few students what a "quarry" was, since it was in their notes. Students were not sure. Monica explained that a quarry was where Fred Flintstone works and many students responded with familiarity to what a quarry is. Paula then looked up the definition in a dictionary and read it to the class in both English and Spanish. Paula also found a rock she thought had quartz because a scientist once told her what quartz looked like... Raul found a fossil and was not sure what it was. We concluded it could be rugose coral but also that we would ask a scientist. More students filtered into the classroom at around 10:30 am (from special instruction) and Monica transitioned with a bathroom break. I was able to casually interview a few students before the break, change the tape here, and casually interview a few more students following the break. After the break, the first group of students working with fossils became "Fossil Leaders" and observed fossils together with other students. Monica pulled a smaller group aside to read "Fossil Fever" to. When students regrouped and fossils were put away, I explained the Fossil Finders project to the students and why they were so important to our research. I feel that this is also being explicit about science-- social science. They were curious about what I was doing in the classroom, too. Students then turned to their Tricky Tracks stories and shared out ideas. Monica guided student thinking (though I disagreed with her point that bigger footprints=bigger animal in Tricky Tracks). I attempted to interject that students need to provide evidence for their explanations. When I asked what the evidence was for their stories, students pointed to Tricky Tracks. When I tried to ask about coming up with explanations, I don't think I was clear enough. Today, I played a more active role in the classroom, following a discussion with the Fossil Finders team. We are using a Participatory-Observation approach and supporting our teachers; not evaluating how much they picked up during our PD (at least I am not in my research). Students will pick up Fossil Finders materials again following Thanksgiving break.

### **MV10-MV11\_120108\_FossilMeasurements (2 tapes)**

This is the Monday following Thanksgiving break. In this lesson, Monica begins with a smaller target group of students (8 people) who are the Fossil Finders Leaders and demonstrates how to measure length and width of fossils on the board. She briefly reminds students how to convert from centimeters to millimeters. These students practice measuring fossils. Common mistakes that started coming out were: 1) students measuring the whole rock, 2) students having trouble converting to millimeters (especially 1.5 cm when in the .5 is in fraction-form). I moved around the classroom to assist students and answer student questions. Students were jotting notes

into their notebooks when making observations. I had a great conversation with a small group of girls about fossil imprints and how a clam could leave a fossil that is smooth. We looked at shells when discussing this. We also considered how one of the fossils could be shiny and that it perhaps contained shell material. After break, Monica began to introduce the datasheets to a small group and asked me to introduce the data sheet to the other group of students. Two groups were left on their own but had lots of questions. Tomorrow, we will need to work with the other 2 groups. Monica wrapped up class by reviewing measurement conversions. She is not certain whether students are ready to move on to the actual sample set.

### **MV12-MV13\_120208\_FossilDataSheets\_ReadAloud (2 tapes)**

In this lesson, Monica works with Fossil Finders leaders to review the data sheets and discuss fragmentation. These students then practice making measurements of Monica's fossil collection [from summer 2008] and recording their data on the data sheets. Some students still having trouble (Nelia thought an entire rock was a fossil; Juliana had some mistakes in her cm-mm conversions). Students are mostly identifying the fossils though and are engaged in the activity. I walk around and answer student questions. The video camera remains focused on this first group. Another group of late-comers comes in [Alyssa...3 more] and Monica asks me to work with this group individually to walk them through the data sheet. We get into a conversation about fossil coloration, fragmentation, students crowd around and are eager to ask questions but we run out of time. Bathroom break. Monica reconvenes the class with a read-aloud activity from the Fossil Fever book. As she reads, she asks students to make predictions using evidence. She uses the example from the book of finding fossils in the desert to probe students about environmental changes. She then demonstrates an image of the environment trilobites and cephalopods lived in [she just happened to have this from previous instruction] and students talk about the fact that the organisms lived in an ocean that was tropical. They draw on examples of their knowledge of tropical oceans. I then probe students to consider what the environment of New York State must have been like if there were trilobites, etc. Students did not gather that it was covered by ocean water... will Monica get to this later? Students then went back to their desks to continue working on their Tricky Tracks stories for the rest of the time-period. A few students presented their stories. Two students went to the school library to get out books on fossils. They bring them back and show pictures to me, Monica, and the rest of the students. Monica talks about the type of connection that is: self to world, self to text... [is this a literacy strategy?]

### **MV14\_120308\_TrickyTracksStoriesContinued**

In this lesson, Monica works with the Fossil Finders leaders on their Tricky Tracks stories. We listen to four students present their scenarios and Monica comments that the stories have to tie back to the Tricky Tracks poster. Students

continue to work on their stories at their desks and other students choose to conference. Camera is mostly pointed to students doing individual work during class time. At the end of class, Monica puts up a word-wall (no footage of this). Other notes: Today was a shortened day (~45 mins) and students mostly focused on writing. At first, the class went down to the computer lab and students were going to browse through the Fossil Finders website and comment on it. However, the lab schedule was changed to Mondays. From now on, students will be in the computer lab on Mondays from 10:30-11:30.

### **MV15\_120808\_PreppingScientistQuestions**

### **MV16\_120808\_ReadingComputers**

Today's class is cut short with assigned computer-time (during which students need to complete reading and math modules). Monica has students working on Fossil Finders stories. Students are also preparing questions to ask the visiting scientist on Tuesday (the next day). The camera is pointed toward instruction while I am interviewing students one by one in the back corner of the classroom on their views on science. The clip needs to be reviewed. In the second part of this instructional period, students were filling out required computer-based modules (for about 20 minutes; unrelated to Fossil Finders). During the last part of this instructional period, students are using "Ask a Scientist" on the Fossil Finders website to type and submit a question to the Fossil Finders staff. After submitting their questions, students browsed the Fossil Finders website. Students were interested in looking at images of fossils and knowing what they are. They were also very excited to find their teacher on the website! Though footage of this day was not overly informative for research purposes, student comments on the website are great and may be informative for further development and modification of the site. Some student comments: too much text, not enough images. How could our website have sections for students to "find" fossils, engage in a story, etc.? Monica has many recommendations. It would be great to get a write-up from her.

### **MV17\_120908\_AskaScientist**

In this session, Trina, a visiting scientist from the Museum of the Earth visits Monica's classroom. Students have prepared questions for Trina prior to her visit. The class period starts with the Fossil Finders leaders (a group of 8) while other students are receiving specialized instruction. Interaction begins with an introduction to Trina and Trina passing out rocks and moving around the classroom talking to students about fossils. After about 5 minutes, Trina draws a cephalopod on the board. At 9:00 there's a great example of Trina validating classroom knowledge: "we thought it was a horn coral..." Monica challenges Bianca's guess of a particular fossil. The class then moves into a question-answer session focused on the questions that students



have prepared for Trina. Monica integrates Trina's responses to connect to what students have been learning. For example, Trina mentions that we went on a fossil dig in North Dakota. Monica points out where N. Dakota is and asks students to name the capital. Students continue to ask question for the remainder of the session. A few example questions include: Why do you like studying fossils? What do you like about being a paleontologist? Do you work with other paleontologists, and how? Do you have a favorite fossil? How big can fossils get? What do you need to do to be a paleontologist? [some of these questions lead to great moments in which Trina talks explicitly about NOS. \*At 25:00, Trina says "we thought this one was a crinoid and it was a cephalopod" [is this about revisiting findings? Tentativeness of science?]]. A conversation about geology vs. paleontology surfaces and Trina talks about everything being interrelated. A student asks: "How long do you study every fossil that you find?" Trina replies: "It depends on what I'm studying it for." Trina makes multiple references to the fact that students are studying the very same fossils she does. Monica pulls out a diagram of what organisms looked like when they were alive. Rual makes a connection that NYS was once covered by ocean. [\*I am adding follow up interviews for focus students to learn more about their views on science after the experience of meeting a scientist].

### **MV18\_120908\_2\_Fossil FindersInvestigation1**

In this lesson, students begin the Fossil Finders investigation. Monica rearranges the desks and breaks the students into their Fossil Finders groups. She gives out instruction: pull out notebooks, rulers, magnifying lenses, identification card. She then assigns roles to each student in the group. She frames the importance of these roles—check each other's measurements to reduce human error. Monica then takes some time to go over the data table and instruct students on how to fill it out. She frames importance of accuracy here—"this is the research Miss Trina is going to be using." "Fossils tell stories..." "When taking notes, be more aware of the word wall." At 9:00 Monica is still providing detailed instructions; include date, everyone's name, sample number... Students begin measuring and identifying fossils. Trina, Monica, and I are moving around the room to help students identify and measure fossils. Some students have questions; Trina spends time talking to a student individually that had missed class. I ask Monica: "how will students know which fossils they've already recorded?" "They'll know," she says. Monica then shares "I really like that students are working with something authentic." At 35:00 Trina comments on a fossil sample students find—it's rare. Also, in this lesson, Trina lets Monica know that it was the one that she collected over the summer. At 37:00 Monica invites a few more questions for Trina. Conversation revolves around the images on the poster board 40:00. What are some tools that paleontologists take into the field? Trina redirects question to students who've already heard her give the response.

Alyssa blurts out “paper toilet.” Other students laugh. A direct translation to Spanish though would be papel higienico... Trina talks about higher-level schooling as a pathway to paleontology. Monica talks about how people get to study what they really like in higher level schooling. Students will continue the Fossil Finders investigation the next day.

### **MV19\_121008\_Fossil FindersInvestigation2**

Monica needed to attend to a student meeting. I start the day going through student notebooks. I’ve been photographing student work to document, instead of photo-copying. This way, it’s digital and in color. Monica gets students into groups at around 10:20. Students are setting up, shuffling in from break. At 6:00, Monica asks students to explain what they’re doing (a continuation from yesterday’s classroom experience). Monica is facilitating handing out samples and equipment. I move around to room and work with student groups (through 23:00). I ask students what they’re finding and suggest a way to keep track of the fossils they’ve already looked at. Monica probes students on how they are certain they are not duplicating data. Monica checks for student understandings of the task at hand and what they need to record. Brandon says he counted every single fossil. At 39:00, students are almost done. Monica needed to slip out. As students are finishing up work, I remind them to write notes and reflect on what it was like to meet a scientist in their notebooks [did they?]. At 54:00, Monica asks students to put data sheets into fossil sample bags. Tomorrow morning, they will be entering data into the database. Monica revisits students’ graphic organizers for the Tricky Tracks stories and the need to have this completed. Monica wraps up this classroom session by reading a segment from a book. She makes a reference to the Fossil Fever book and calls it a Text to Text connection. She also makes connections between the book and what students were doing in class. Monica reminds students that Raul made a “discovery” yesterday—that NYS was once covered by water. Students will all need to find something neat in their books to share [I’d like to get a list of library books they’ve taken out for reference]

### **MV20\_121208\_VerifyingData**

In this 28 minute segment, Monica is working with a small group of students to review and confirm their identification and measurements. At 3:45, Monica states: “we’re doing double-checking. It’s what scientists do, they double-check.” In this clip, it is interesting to see how students observe, identify, agree upon, and defend their explanations. Monica solicits questions to students, such as “Renee, do you agree with him?”; Encourages a sense of ownership, such as at 12:30 “Alyssa, you were in charge of measuring, right?”; and defers authority to students “what did we decide here?” Monica feels that working in a smaller group is more effective and she

can monitor student learning but it is taking more time than she expected and that there wouldn't be enough time for data entry [16:34]. Alyssa describes how she knew it was a particular fossil [26:54]; "the biologist told us."

### **MV21\_121508\_DataReview**

In this 42 minute segment, Monica revisits double-checking data with the same small group [my dad joins me for data collection on this day]. Monica is working with Raul; how can you tell it's a brachiopod? How can you tell the difference? They both have ridges... Raul demonstrates how he measures length and how we measures width. Measure it again, I got something a little different [one student shares that measurements are like a compass; length is North to South and width is East to West]. At 12:42, I talk to Monica about what she's doing. I say "are you finding a lot of mistakes?" Monica says "No, actually pretty good." Sometimes the length and width in the right places; great identification; also comfortable with fragmentation and coloration. Once Raul is done, the group will enter the data. Monica and Raul are measuring the same fossils. Monica: What did you get?; Raul: 19; Monica: Yep, I agree with you.

I have a small discussion with Monica and Raul about the possibility of there being horn coral in the group. Monica: Did Trina also say so?; Raul: Oh, yeah!; [17:45] Raul: this looks like...

Other students join the group after specialized instruction.

Monica: "What did you decide on coloration?"; Monica: Do you all agree it's a whole?

Students: No; Monica: It's that little thing—I made a mistake

31:00 "Anything else on that rock that we need to report?"

36:00 Girls discussing measurements in Spanish.

Students continue to work and converse in small group throughout this lesson.

This was the last video clip of Monica's classroom. We need to find out how data entry went in her classroom and how students responded to charts and graphs of their data. How did they make sense of it? Include these questions in interview with Monica.

## **APPENDIX C**

### **Video Data Content Log**

Fossil Finders Instruction/Video Content Log				I N Q	N O S	I C
Date	Title	Time Cu	Episode			
9/30	MV1		<b>Tricky Tracks</b>			
		0:04:00	Okay to write in Spanish			x
		0:06:40	Interview students about segment 1			
			What did you see?			x
		0:08:17	MV and a bird named "Pancho"			x
		0:08:30	MV What we did... points out			x
		0:09:11	Students share out what they thought			
		0:15:34	Discussion of part 2... why were dinosaurs moving?	x		
		0:17:34	Discussion carnivore/herbivore			
10/6	MV2		<b>Dinosaurs &amp; Tricky Tracks Backwards</b>			
		0:03:07	Scientists put dates on the top of the page; tasks		x	
		0:12:00	Isabel and Paula initial fossil observations			
		0:15:30	Is a shell a plant or animal?	x		
		0:22:00	A rock is not a fossil			
		0:28:00	MV's instructional rationale	x		
		0:31:48	Dinosaurs- Building from ss prior knowledge	x		x
		0:47:25	Translating Instruction			x
		0:58:58	If scientists all have the same facts...		x	
		1:04:48	Student Notebooks			x
10/7	MV3		<b>Vocabulary &amp; Fossil Exploration</b>			
			*From 28:19- 32:19 very engaged classroom			
		0:25:30	"Dame verlo"			x
		0:29:28	"Is this real?"			
		0:30:09	Fossil Finders logo has a trilobite	x		x
		0:30:37	Student interaction; informal Spanish			x
		0:32:45	Student responses to "what are you seeing?"			
		0:36:01	MV "It's so hard not to give answers"	x		
		0:36:34	You've been doing paleontology; what does it mean?			x
10/20	MV4		<b>Meal Worms and Measurements- Self Recording</b>			
	Day 1	0:00:00-0	You are making inferences; different treatments are variables		x	
	Day 2	0:33:20	We were making inferences based on what we saw		x	
		0:33:38	MV: Scientists have to keep accurate notes		x	
		0:37:09	Cm to mm; connection to FF			
		0:40:00	Observing mealworms	x		
		0:51:14	MV: Look at mealworm color	x		
		0:55:29	My mealworm is different!	x		
10/24	MV5		<b>Meal Worms and Measurements - Self Recording</b>			
			*Students present their measurments of mealworms and futher observations			
10/28	MV6		<b>Meal Worm Reports - Self Recording</b>			

		0:09:57	Sharing connections to previous experiences and home experiences			x
		0:10:51	Does it look like a cucarracha?			x
		0:10:55	En Puerto Rico, yo coji...			x
		0:15:21	The life cycle includes...			
11/17	MV7	<b>Tricky Tracks Stories: Setting</b>				
		0:02:03	Scientists have the same evidence but different conclusions	x		
		0:21:40	You can be a paleontologist			x
		0:49:00	Students sharing stories (reading outloud to class)			
11/24	MV8	<b>Fossil Identification</b>				
		0:03:30	"Oh snap, I found..."	x		
		0:11:20	"Hey Ms. V., I think I found a..." MV collaboration	x		
		0:13:00	What is a quarry? Fred Flintstone; Paula looks it up			x
		0:17:00	What a quarry is... conversation; fossils in rocks			x
			Rest of session what ss are seeing, interviews			
	MV9	<b>Small Group "Fossil Fever" Reading, Tricky Tracks Stories</b>				
		0:01:00	Interviewing Paula candidly about fossils			
		0:16:00	This is a brachiopod... Miguel showing me			
		0:26:20	R: Why your participation is important to this project	x		
12/1	MV10	<b>FF Leaders Fossil Measurements</b>				
		0:02:25	MV demonstrates how to measure fossils on board			
		0:10:09	MV explains length and width in cm			
		0:32:20	Students measuring; Raul measures rock not fossil			
		0:39:10	Alisa and Paula observing; use of Spanish			x
		0:40:00	Call R for help; questions			
		0:41:40	R questioning: what sort of inferences if fossil is broken?	x		
	MV11	<b>Class Fossil Measurements</b>				
		0:06:50-0	What are we doing today? Question/Answer			
		0:18:30	R questioning: How do you measure this fossil?			
		0:32:00	MV going over worksheet with ss			
		0:41:30	MV: I think you're right...			
		0:42:00	Alisa with rock; MV "deme"; my eyes are not that good			x
		0:43:39	Raul with a question; collaboration btwn ss and teacher			
		0:56:25	MV: Be careful measuring; cm vs mm			
12/2	MV12	<b>FF Leaders Data Sheets</b>				
		0:00:00-0:	MV traditional instructional approach; IRE	x		
		0:14:40-0	Student activity; identification and measurement	x		
	MV13	<b>"Fossil Fever" Read Aloud</b>				
		0:00:47	MV: People are going to live where there's water			
		0:08:29-0	MV: Why a mistake? What evidence do you have?			
		0:12:43	How could anything live here? [reading]			
		0:13:53	What can we infer? [conversation]	x		
		0:14:40	What have we been finding?	x		
		0:16:01	I want to show you something... [poster]			

		0:17:14	What type of climate was it?	x		
		0:17:39	Who knows about how fossils develop?	x		
		0:19:43	R probing ss; what did NYS look like in past?	x		
		0:24:00	MV will we see coral in NYS?			
		0:29:00	Good questions; library for more resources			
			Students back at desks writing...			
		0:49:48	Renee & Isabel share books from library			x
		0:52:46	Renee shows MV book; text to world connection			x
		0:54:45	She found a brachiopod; show everybody			x
12/3	MV14		<b>Tricky Tracks Stories</b>			
		0:00:36	Do you have your Tricky Tracks story out yet?			
			Bianca and Isabel, are you two ready to share today?			
		0:02:00	Bianca: Once upon a time...			
		0:05:12	Isabel presents (dinosaur jail); tries pronouncing their names			x
		0:09:40	MV: we need to connect back to the TT stories	x		
		0:10:54	Renee presents (dinosaur fight for food) incorporates TT	x	x	
		0:14:34	Avanza; Carolina presents (dinosaurs fight over a chair)			
		0:17:55	MV: we need to connect back to the TT stories	x		
		0:21:15	CSI; Need clues in story [evidence]			
			Independant working rest of class on TT stories; informal conversations with ts			
		0:35:42	Ms. Sanchez "the feather that" informal vocab discussion with ss			
		0:43:16	MV informal w/ss; Marcelo- I found a fossil in my back yard			
12/8	MV15		<b>Prepping Scientist Questions</b>			
		0:00:05	Wordwall scan			
		0:04:28	Science journal, primary source (interview)			
			Prepping questions for scientist			
		0:05:55	What is a paleontologist? Look it up			
		0:06:40	Review vocabulary about fossils for stories			
			Students informally working on prepping questions for scientist			
		0:16:10	I need to see a fossil to ask a question; a real one			
		0:17:20	MV brings fossils; guides questions			
		0:17:38	Norma shares question; What kind of fossils do you study?			
			Is that a good question? It's an excellent question			
		0:39:57	Paleontologist; what does a paleontologist do?			
			Students informally working on prepping questions for scientist			
			[I am interviewing BT in back of classroom; class goes down to computer lab]			
	MV16		<b>Fossil Finders Website Comments</b>			
			Not FF related curriculum; students online completing reading assignment			
		0:24:00	Students getting onto FF website			
			Student scientist; Ask a Scientist Form			
		0:35:49	I've already got 2 questions; R asks ss what their questions are			
		0:36:52	Typing up a question			
		0:38:20	Students collaboratively spelling out dinosaur			

		0:38:38	How do you write brachiopod?			
		0:39:30	R: Can you tell me what you like about the website?			
			Review this section later for program evaluation purposes			
12/9	MV17		<b>Ask A Scientist: PRI visit</b>			
		0:00:00	Miss S (scientist) interacting with student...waffle, starburst, beautiful fossil			
		0:00:25	MV describes what is occurring in class today			
		0:02:32	Miss S: See the little bumpy things; when it was alive			
		0:03:16	<i>Miss S: Live together in a family, not walk around and be boyfriend and girlfriend and get married some day</i>			
			[overlapping group conversations]			
		0:04:35	We thought it was the cr...crinoid! It's not a crinoid			
		0:04:55	Miss S Crinoid vs. Cephalopod mini-lesson			
			compare/contrast relate to organisms today			
		0:07:49	We wanted to share coral			
			Crinoid example to compare; teeny tiny like a flower stem			
		0:08:54	MV: It may look like that but it's not that.			
			I know it's not b/c a scientist told me			
			Bianca is going to argue that that's a fossil			
		0:09:15	Bianca's going to prove that that's a fossil			
			It's gas that got trapped in the land			
		0:09:39	Miss S: So which ones are your favorites?			
			Student responses-- clam, trilobite...			
		0:09:47	MV: Who has some interview questions for the scientist?			
			Me, students raising hands			
		0:09:51	<i>Miss S: I was reading them last night (submitted in lab day before)</i>			
		0:10:01	<i>Just quiz me away, is that the plan, just quiz me</i>		x	x
		0:10:06	Well, they're doing interviews but if you wanted to they can ask about fossils too			
			<i>Miss S: Shall I sit here and be interviewed?</i>			
		0:10:35	Renee: What is it like being a paleontologist?			
			<i>Miss S: Like being anything else, but I could go hiking and being outside. Did not want to be in an office behind a desk all day</i>			
			<i>I get to go to exciting places, North Dakota, rattlesnake, carry hammer. A lot of fun, a lot of work, but learn something everyday</i>			
		0:11:36	Annamaria: How long have you studied to become a paleontologist?			
			<i>Miss S: High school, did the math stuff, the science stuff that everyone else did, paid attention, did 4 years at a college</i>			
			<i>I had to go to school for another 2 years</i>			
			<i>I did a bunch of other stuff so it wasn't all science all the time</i>			
		0:12:29	MV: Points out N. Dakota on the map which everyone should already know because they've been studying states			



			Anybody know the capital? Ms. Sanchez is going to have a fit			
			Atlanta?			
		0:13:06	Isabel: Do you study fossils all over the United States?			
			<i>Miss S: I try to but just like geography you might start with the US and then you learn about other places...Know the world, I study fossils in different places so that I can understand similarities differences in fossil. North Dakota, leaf fossils; Alaska, clams just like you have; Ohio, Horn corals and cephalopods; North of Venezuela, corals</i>			
		0:14:20	Carolina: How long have you worked with fossils?			
			<i>Miss S: Well, I met my grandpa when I was born!</i>			
			MV: Starts laughing, explains joke to students (no uptake?)			X
		0:14:48	<i>Miss S: First class where I got to see fossils was first year in college-- six years ago</i>			
		0:15:05	Marianella: Why do you like studying fossils?			
			<i>Miss S: an adventure, not worth a million dollars but like finding a treasure. And I like to figure out what it looked like when it was alived. The best part is the imagination</i>		X	
		0:15:45	Paula: How long did you study for?			
			<i>Miss S: It depends. In college, I studied every night. Traveling all the time, you do the collecting first and then at night you're sleeping in a tent or with people. When you take it back you spread it out on desks and tables and study around the clock. If you do it right, a little at a time.</i>			
		16:34	Annamaria: What do you like about being a paleontologist?			
			<i>Miss S: I love getting to see different things and I love to teach. So, I really like to hang out and make you guys like it too. I'm a big geek, and everything because everybody is like... ooh, scientists. And, I think I'm a pretty normal person. The more people I can get to like fossils... I can be in the in-crowd like Ms. V.</i>			
		0:17:11	Ms.V: My son tells me I try to be too cool. Boys and girls, be sure you don't ask the same questions			
		0:17:37	Renee: How does it feel working as a paleontologist?			
			<i>Miss S: Different paleontologists do different things...museum, teaching, oil companies... they might feel different</i>			
		0:18:27	Bianca: Do you work with other paleontologists and how many?			
			<i>Miss S: Good question. All the time. My teachers become my friends the more I work. College now go out to field with saved me from rattlesnake, write papers together. Second college graduate school we're writing a chapter together. Conferences we do 10 minute presentations just like you do in class and we listen to each other talk and give recommendations.</i>		X	X
		0:19:36	Isabel: Do you have a favorite fossil?			
			<i>Miss S: I really like the brachiopods and every now and then you'll see something funny called encrusters and I really like those. And some dinosaur fossils</i>			
		0:20:16	Paula: What kind of dinosaur fossils do you study [unclear]			

			<i>Miss S: I study actually a lot of the same stuff you're looking at and hopefully you'll help me pick out the really cool fossils in your stuff and when I hear about it it can add to my research. And, in my acknowledgements I can say Ms. V's class helped me collect some of the data</i>		X	
		0:20:49	MV: Boy and girls, how big do you think these fossils that we've been analyzing; how big do you think those creatures can get?			
			Annamaria: 5 cm? MV: we need our rulers; can you help us with that Miss S?			
		0:21:22	<i>Miss S: Sure I can. Some of the biggest fossils you won't see a whole piece of. Cephalopods can be as big as the white board-- the whole length, trilobites can be this big by this big [gestures with hands]; I don't think the ones you're looking at; sea scorpion 15-18 feet [draws on the board]</i>			
		<b>Second group of students comes in [from target instruction]</b>				
		0:22:50	MV: Introduces Miss S to students that just came in ; rearranging, hurry up Matias por favor			
		0:23:28	<i>I'm going to ask your group; I want you to share how big some of these fossils can get; you already know.</i>			
		0:23:51	Raul: 15 feet; What? A cephalopod; Bianca: A scorpion			
			MV recaps some of the instruction from the previous segment: remember we thought this was a crinoid? It's not, it's called a cephalopod, which is like a squid			
		0:25:05	<i>Miss S: What was that guy? A eurypterid, you don't have to remember that. Crazy word. I don't know why paleontologists like to pick weird names from latin words; sometimes sort of silly</i>		X	X
		0:25:33	Alisa: Did you travel [inaudible]?			
			<i>Miss S: I did, do you guys remember where I traveled? [to first group of students] Everyone say one. Students one by one: Europe, Ohio, Alaska, Venezuela,</i>			
		0:26:19	MV: emails last night, go around and say names			
			Students introduce themselves "Hi, I'm....."; Miss S: "Hi ...."			
			<i>Beautiful names but I might forget them</i>			
			R: Miss S. remembers fossil names better			
			MV: Any questions from this group?			
		0:27:49	Brenden: What's it like being a paleontologist?			
			<i>Miss S: I like to travel, so it's useful for that. It's a mix of doing things like your homework, sometimes behind your desk. It's fun b/c I get to go places and see things but it's just as much work as anything else.</i>			
		0:28:36	Jahaira: What kind of fossils have you found?			
			<i>Miss S: I found fossil plants, fossil t-rex but only ever little pieces, mosasaur-- not a dinosaur; and I wrapped him up in plaster. Can you imagine what it would be like to wrap up your desk. And, a lot of what you are looking at too?</i>			
		0:29:28	What is the best fossil you found?			
			<i>Miss S: I don't know. I can't pick a favorite. I found some nice leaves that look just like a leaf that fell from a tree.</i>			
		0:30:00	What do you need to do to become a paleontologist?			

			<p><i>Miss S repeats [Ms. V did you mean?] Both: Good question; Know about the rocks because we can't see these things alive, so we study dead animals, so I have to know a lot about biology not necessarily cells but I need to know how organisms lived because we look at modern clams today and we look at how they lived and how they're shaped and then we look at the clams in the rocks and we say, well this is shaped like the one today so maybe they lived the same... we had to dig 3 1/2 feet into the mud to find him. So we have to know about the rock too... both biology and geology. How rocks works, how rivers works, and then put it all together. Just pay attention in science mostly and use all the little bits of science together.</i></p>			X
		0:31:34	Carolina: Do you have a favorite dinosaur?			
			<p><i>Miss S: I don't like backbones. [Laughs]. I study invertebrates, but if I had to pick... allosaurus.. Armored plates club for a tail.</i></p>			
		0:32:18	Isabel: Did you always want to be a paleontologist?			
			<p><i>It's embarrassing, I've wanted to be a geologist since the 3rd grade. I went hiking with my grandma in the woods and I picked up a lot of neat rocks and put them in her pocket. Then I realized that.... I liked paleontology a little more.</i></p>			
		0:32:54	MV: Hold on for a second. Who knows the difference between geologist and paleontologist is?; Isabel [exchange] Who can tell me what a paleontologist does?			X
		0:33:09	Matias: Study fossils			
			MV: And when they study fossils, it's called the study of paleontology, right? And what is that? Who remembers?			
			Isabel: They study animal fossils and plants			
			MV: Animal fossils and plants fossils from when? From now?			
			Isabel: No, prehistoric times.			
			MV: Geology, now look at Geography...landforms... What do you thing OLOGY means. Palenotologists....What do you think a geologist would study?			
			Paula: Maybe land forms [MV: Landforms] and water			
			MV: Maybe what water does to land. So she used to study land, earth, but she decided ...			
		0:38:24	<p><i>Miss S: Geology is really cool, because it's the study of GEO, the earth. Oceans, boats, currents, climate change, wind patterns, we study because it's all interrelated, wind patterns are based on where the land is... so geology is really cool because once you learn a little bit about it you can go into meteorology to be on TV and do the weather, oceans and be a marine biology, the core is rocks, all really cool because it's interconnected.</i></p>			
		0:38:42	How long do you study each fossil that you find?			
			<p><i>Miss S: It depends on what I want to do with it. A person that finds a T-rex fossil; there've only been 10-15 ever found so they sit and study, 30 different paleontologists will study one leg bone but for us, you can see that we can find hundreds of brachiopods in just a scoop full of rocks. We'll measure all of them, we'll look a 3 or 4 thousand of them. Some paleontologists will look at one for 10 years, one fossil. Other paleontologists will look at 1000 fossils in one year! ooh ooh ooh Ms. Meyer!</i></p>			X

		0:36:38	R: I think that's why we need your help, guys. There are lots of brachiopods. I don't know if Miss S has time to go through them			
			<i>Miss S: No, cause I've got to do things like this and go out and collect. So, I don't have time to sit down and measure things all the time. I haven't even had a chance to go through them. You might find some things, take some pictures, make some notes, measurements, and that will tell me should I go back and look at your sample really intently.... or Ms. Weigand's class and it doesn't have a lot of fossils... I can answer all of these questions once...</i>			
		0:37:50	Who thinks that they might want to pursue a career in paleontology? [Students raise hands; so does Miss S]			
		0:38:06	Alisa: Does it take a lot of time to learn about fossils?			
			<i>Miss S: It depends. It I know a lot about it, I can do it like that! Sort of like flowers, trees, streets on a road... if you're new to an area you don't know any of the streets, or if you're new to a field, but if it's your yard, or your garden, or your home town.... when I'm around here I know a lot of the fossils but when I go to Canada or Michigan it takes me a long time.</i>			
		0:38:49	Matias: What kind of tools do you use to study fossils?			
			<i>Miss S: So I have a rock hammer, sort of like what masons use to do roof work, a pick-axe, plaster, little paint brushes to move dirt out of the way, an "all" sort of like a pencil with a flat edge on that to hammer with, and one of the coolest, a little pocket knife that my grandpa gave me. Sometimes you can wiggle the shale... and then I make sandwiches</i>			
		0:40:26	Sub: Is toilet paper part of...			
			<i>Miss S: Yes, toilet paper is one of my key tools as well because you've felt the shale. If I find a sample, I don't want to just throw it in the bag with all the other rocks. What I do is wrap it up in a lot of toilet paper. One last question... Paula</i>			
		0:41:02	Paula: What kind of climate do you live in?			
			<i>Miss S: That's a good question. What kind of climate is this?</i>			
			MV: Wait wait... how about... even better than that. She lives in the same climate we live in. Why don't you ask her what kind of climate the fossils may have lived in.			
			<i>Miss S: Oh, that's a good question. So, we know the fossils came out of NY, right? Miss V. will you point to NY for me? [Ms. V not seeing NYS]</i>			
			Students: Right there, right there! [It's the pink one?]			
			MV: Ai Maria! Muchachos, ha ha, I don't know where I am!			
			Miss S: So, let me sneak again. [Miss S steps up to the map] Thanks darling. So that's about here-ish, right? Everybody agree? Where's the equator? [PA announcement] Here's the equator			
			MV: Pay attention boys and girls			
			<i>Miss S: What's the equator like?</i>			
			Students: Hot			
			<i>Miss S: Hot, humid, right? Rainforests, right? So, just above the equator, say Florida, Mexico, Caribbean Islands... what is that climate like? [Hot] But, like a beach. You all lay out and tan.</i>			



		0:05:22	This way, say I measure 3 mm but then the other person measures 2.5 millimeters, then we're going to check. There can be human error.			
		0:06:27	If you forget which way is Length and Width, do the illustrations help us?			
		0:06:48	Everyone needs to record notes in their science journal; charts will be put into the computer			
		0:07:11	This is the research that she wants to see...and that she's going to be studying and she's going to be comparing our fossils to Ms. Weigand's class. Fossils tell stories. Ask questions, especially since we have a scientist in the classroom. When taking notes, be more aware of the word wall and include vocabulary.			
		Student group discussing jobs				
		0:08:47	Sample number and subsample number; asks Miss S to confirm			
		0:08:58	Miss S clarifies [one is actually the weight of the bag/insignificant]			
		0:09:16	<i>You can even notice if you read the bag that it was collected by Miss V.</i>		connects	teacher to
			MV: Oh, so these is the ones that I chopped			
			<i>I tried to give teachers their own bag...</i>			
			MV tells story from this summer; no hat; back to describing number and subsample number			
		MV passing out materials; students start talking/working in groups				
		0:10:26	MV: At this time, you should have the date and everyone's name on the data chart [Isabel takes chart from Matias and begins delegating]			
		0:11:27	Miss S & Bianca talk; high five			
		0:11:40	MV: Cuanto tu tienes aqui, how many magnifying glasses do you have?			
		0:12:15	One, two, three, four... I know everybody is excited and am happy that all are engaged but what kind of voices? [whisper]			
			We're not rushing; this is the first time we're looking at these samples			
		Groups still deliberating jobs				
		0:13:48	We don't have to rush; this is the first time we're looking at these			
		0:14:06	If you're in charge of identifying...			
		0:14:39	Bianca: Isabel, I'm not very good at identifying this rock; Isabel: Look at this one [trades rocks] (Mr. Rivera, sub, in in the way here) [sub starts interacting with students and working on fossil identification; MV slips out of classroom; Mr. Rivera intermittently blocks camera]			
		0:17:04	[R approaches group] Answer Bianca's question; Miguel showing a fossil: looks like a brachiopod;			
		0:18:54	[Miguel starts playing with magnifying lens]			
			Isabel: Wait, let me see that one; Miguel: Looks like the inside of a shell; It's a clam...			
		0:19:45	[Miguel starting talking in Spanish] Mira, se parece a una...se aguanta; [MV approaches] Que haces, papito? Okay, busca, look for fossils.. You could take notes.			
		0:20:19	MV: I like the way Paula has her notebook open to take notes.			

		0:20:32	Bianca to R: We found a piece of a brachiopod here [R approaches desks and engages in conversation with Bianca]			
		0:20:50	[MV approaches desks and begins conversation with Carlos] Tu puedes dibujar eso; y tu sabes eso; you've done that.			
		0:21:32	[R approaches group]			
		0:22:22	MV: [to class] We're not rushing boys and girls. Don't rush to get data in there. We can analyze and look and check it out.			What does it mean to
			Group deliberating jobs; Matias asks group members to vote [sub approaches]			
		0:23:53	No, millimeters is... [Miss S approaches group]			
			You can pour it all out if you want to, it's okay. Just make sure everybody is not doing it twice, you know what I mean?			
		0:24:14	[R moves camera to another group]			
			Group engaged in measuring fossils; converting measurements to mm			
			[R engaging with group] Nella and broken fossil; Alisa and identification table			
		0:28:40	[Miss S talking to student about paleontological work in background]			
		0:29:40	Change camera angle to capture conversation			
			<i>I'll look at my 20 fossils like you guys are doing, I will measure it, I will label it... look for it see if it has it... that's a typical day...those are like little hypotheses little science experiments... ketchup in macaroni and cheese... I think it's weird.. once I thought I wanted to be a scientist... then I realized I'd been a scientist all along.</i>			
			Marianella asks question			
			<i>...I've been a paleontologist for 5-6 years... when I was in college</i>			
		0:31:43	<i>You're asking the same question scientists ask; I consider you a colleague</i>			
		0:32:53	[MV to class] We've been looking at... has anybody found any trilobites? This group found a cephalopod; we're measuring our fossils in mm; fragments; how big did Miss S say a trilobite can get?			
			15-18 feet			
			<i>Well, that's a eurypterid...A trilobite can get 3 basketballs big</i>			
		0:34:34	Matias: Miss S... Miss S...			
			Isabel: how come you're not doing your job?			
			Matias: Miss S, what's this?			
			<i>Ahh...interesting!We're going to call it a cephalopod, but it's not really. It's a conularid because they're related. It's really rare, etc...</i>			
		0:35:59	Matias [in Spanish to Carlos]: algo este... el tren [dancing with shoulders] por que, es rare. I just found something rare, right here!			
			Isabel shows trilobite: here's the nose and here's the head			
		0:37:07	Boys and girls, we have time for 2 more questions for our scientist [buzz students talking I've got a question]			
			MV: If you have any burning questions... we need to be respectful because whatever one of our classmates asks we can learn from too.			
		0:37:42	Paula: Did you study with other archeologists?			

			Did I study with other archeologists [MV is she an archeologist? Paula rephrases question: Do you study with archeologists?] Miss S talks about layers of rocks and different layers of what they study. Usually we'll be studying way down here and they'll be studying here.			
		0:38:55	Renee: What is your life like working as a paleontologist?			
			<i>Some days it's full of travel and I miss my kitty cats, but sometimes it's sitting behind a desk. Each day is different just like school.</i>			
		0:39:22	MV [holding poster]: You were saying earlier when Raul determined that NYS was under water, so that NYS looked something like this, Miss S?			
			<i>That looks like a snail,</i>			
			MV: A gastropod			
			<i>And there's trilobites... etc. sea lilies, crinoid and I'm going to cheat a little, I think that this is horn-coral [PA announcement; Miss S checking Paula's fossil]</i>			
		0:40:55	Time for 2 more questions and then if you have questions that you have for Miss S, how else can you communicate? By email. Let's pick 2 people that weren't here this morning.			
			Joshua: what tool do you use to pick up			
			<i>[Miss S elicits student recalling what she mentioned in the morning] Paint brush, pocket knife, PBJ; all, toilet paper...</i>			
			Marcelo: How many years did it take you to become a paleontologist			
			<i>About 5 or 6 years...</i>			
		0:42:58	MV: Son is in college and wants to be a lawyer... Miss S paleontology, I studied education; when you choose exactly what you want to do you will enjoy education;			
			<i>And chose exactly what you want to do.</i>			
			And you will have fun at the college level; don't worry			
			<i>My minor was in theater, and my minor was in rocks and all...</i>			
			Thank Miss S...			
			R: can we take a group photo?			
			Queso... dame un beso...			
12/10	MV19	<b>FF Investigation Continued (1:11:58)</b>				
			Students moving desks into groups (from rows)			
		0:04:40	MV: Pull out your science notebooks, your pencils, your ID chart			
		0:05:36	Who can tell me in their own words what we're working on?			
			Bianca: we're recording, identifying... fossils			
			And we're putting it, Isabel?			
			Isabel: Fossil ID Chart			
			MV elaborates on instruction. Double check what has not been recorded yet.			
		0:06:57	MV: Who needs magnifying glasses?			
		0:08:27	Alisa [to group about R] She's coming to my house on Friday			
		0:08:35	Renee: On our homework last night, we had [Alisa suggests what it way] no, it was something and it was shaped like this.			
			Alisa:... it was a grasshopper			



			Nelia: No, it was something else			
			Renee: A silverfish			
			R: Have you ever seen a silverfish?.....			
			Renee: it goes through egg, young, and adult			
			Back and forth between Renee and Alisa			
		0:09:29	R [to Raul]: I never answered your question			
			Raul: inaudible			
			R: Does anybody here know who ran...			
			Alisa: I did the big one, I think Renee did the little one			
			Renee: Oh, yeah. It's a half of a brachiopod			
			...I didn't measure this part.			
			R: Okay, somebody show Ricard how to do it instead of asking me			
		0:10:23	[Renee showing Raul how to measure and explains how; Raul and Alisa start playing with magnifying lenses; Fossil related interaction and informal conversation between Raul and Alisa]			
			You're ugly; you're ugly; Miss, am I ugly? R: I think you're all beautiful			
		0:13:03	[Shifting camera angle to second student group; observing fossils]			
		0:13:35	Matias: Hey look, I found a trilobite			
			[Isabel grabs rock] That's not the rock though			
		0:13:56	Isabel: I found a trilobite			
			Matias: Let me see! [Isabel: No! Holds it close. Turns to Ms. Sanchez]			
		0:14:35	Matias: Where's the trilobite? [Isabel starts measuring it]			
		0:17:35	[Shifting camera angle back to first student group]			
			MV: you should have your science journals out			
		0:19:36	[Renee singing song; Nelia bopping head; Kaishela, you're a grandmother-- very conscious segment of camera; performance; Nelia explaining to Raul; mostly offtask]			
		0:24:06	[Shifting camera angle back to second student group]			
			Isabel and Bianca: it's a clam; ... Who's going to measure this?			
			Matias: Me! Bianca: I'm the measurer			
			Isabel to Matias: You're the identifier			
		0:25:32	Matias: Hey, another clam inside out			
			Isabel [assertively]: Then measure it.			
			Bianca: What is it? Let me see			
			[Matias shows Bianca] Bianca: Yeah, it's a clam.			
			It's kind of a round one. It's fragmentation			
			Ms. V said we all measure it...			
			The length is... ....20 mm			
		0:27:23	[Shifting camera to third group]			
			MV to class: So, boys and girls, voices. Get that door please. Everybody should be seated for one second. [addresses Paula's group] Is that big rock one of your fossils?			
			Miguel: Yes			

			Paula: It looks like Texas!			
			MV: Has every group come up with a system to note which fossils have already been recorded? Not duplicating data... Not go back and measure a brachiopod and then think you had 2 brachiopods. Does everybody have a system? Who wants to explain their system? Renee.			
		0:28:29	Renee: After we measure the fossils, we put them on our data table, then we put them in the bag to know which ones were done already.			
			MV repeats; Anybody have another system? Paula			
			Paula: We measured a little brachiopod... measured it and it was 7mm (does not answer question)			
			MV repeats question			
			Paula repeats same response			
			MV extrapolates Paula's system; Paula agrees			
		0:29:43	MV: How do you determine from yesterday? How can you tell you didn't already record from yesterday? How can you tell? Renee?			
			Renee: Inaudible			
			MV: I can't hear Renee cause some people are talking			
			Renee: We know because we know the shape how it looked and the different kind of fossils that we had			
		0:30:30	MV: Okay, another way you can do it.... Thank you Renee, so you're saying... Another way for the fossils that aren't recorded. If there's anything left over today, I want you to wrap it up in paper towel. I want you to double-check your data. Anything that's not recorded, separate it. If there's anything left over, what are we going to do Nelia?			
			Nelia: Put it in...			
			MV: Very good. Everybody understand that? Let's say, what you have in your hand, Joshua...and you recorded that.			
			Joshua: In the bag			
			MV: In the bag, do you understand that, Brenden?			
			Is everything recorded in your bag? Okay, so now you guys are doing the double-check. You're going to go one by and double-check. Any questions?			
		0:32:15	Also, Ms. Sanchez, it turns out the samples were samples I chopped off and the paleontologist kept them by our names for our classrooms. Isn't that cool?			
		0:32:42	R: [to group] So, I found one rock and I'm not sure if we measured it right. Brenden. Are we sure we got the cephalopod right?			
			Brenden: Each thing... The way we did it....			
			R: So you just counted every single rock?			
			Annamaria: No, every single fossil			
			R: Every single fossil, okay			
			Brenden further explains			
			X: so this			
			Annamaria: I found...			
			R: okay			

			Annamaria: I found brachiopods, 3 cephalopods, clams, and one snail			
			R: oh, let me see the snail			
			[Brenden looking for snail]			
			R: You thought it was a snail			
			And then we thought it was a trilobite... [R misses Brenden's question]			
			R: on fragmentation with group... [Brenden: I found another fossil]			
		0:37:03	[Camera shift to Group 2]			
		0:37:57	R: How's it going over here, guys? [It's good] How's it going? [Cool] Do we have most of our measurements? Did we go through all the fossils?			
			We did the little ones			
			We have 2 more			
		0:38:21	[Camera shift to Group 1]			
			How's this group doing [students do not hear] How's this group doing?			
			Isabel: Good...			
			MV [steps in]: Where are your notes, Bianca...			
			Where are your notes, Miguel? Where are your notes, Melinda? What do you have from today? We need to stay on-task. There's one right there.			
		0:40:01	[Camera shift to Group 2]			
			R: How's your group doing?			
			Miguel & Juana: Good			
			Miguel: We found a..... Fossil.			
			Carolina: Not good.			
			R: Not good?			
			Carolina: Because we ...			
			R: Because what?			
			Carolina: Because I haven't found any fossils			
			Miguel: I found a clam			
			R: How big, did you measure it?			
			Miguel: No....			
			R: Wait, who's your group measurer?			
			Juana: Me.			
			Carolina & Miguel deliberate on who the 2 group measurers are...			
		0:40:43	Miguel: 35mm latitude, what?			x
			What about length? 25			
			[Interesting to watch group work here for a few moments]			
			[Then groups goes somewhat off task; boyfriend, Obama]			
		0:43:33	[Camera shift to Group 2]			
			[MV interacting/joking with Group 2]			
			MV: So they ask the paleontologist and she goes; why don't you just ....			

			[MV cracks up; Students laughing; Melinda shows notes]			
			Melinda: Look, from yesterday and today.			
			MV: Excellent, now that's what I'm talking about.			
			[Gives lens to Nelia] Now see what you see. [MV leaves]			
			[Student conversation; how long are your notes from yesterday?]			
		0:44:18	[Raul & Renee; Miss Xenia, he just slapped me with a pencil; R: Is that what we're supposed to be doing for Fossil Finders; Raul: I'm sorry it was an accident...]			
		0:44:46	[Camera Shift to Group 4]			
			Annamaria: Que significa huerte en light in Spanish?			
			Alisa: De algo natural...			
			Brenden: Ancho...			
			Annamaria: Y ustedes...			
			[Renee steps into the camera lens]			
		0:45:00	Renee: I came up with the perfect idea. This looks like Africa.			
			R: Ohh... here, show it to the... wow. It does look like Africa.			
			[Goofing around in front of camera]			
		0:45:46	[Camera panning around room; Stop at Group 3]			
			Miguel: How am I supposed to make note?			
			[Students generally complete with task; goofing around; I ask students to write in notebooks] [Camera on Group 2]			
		0:51:37	[Camera across room capturing most of Group 1 and Group 3]			
		0:52:58	MV steps into room; R and MV talk			
			MV: At this time, you should have a page of notes...			
			Everybody should be able to pull out a fossil, write about it, describe its distinct features, how you were able to identify the species, you should be able to tell me in your own words. You should have the date on the top, did you draw an illustration of the fossil? Karina, do you want to share?			*
			Karina: No.			
			MV: Why not? ... okay, we're not calling out because it's not appropriate... where's .... We need to help Danaesha [new student in class]			
			[Karina shows R notebook; R: so, what do you think scientists do?]			
		0:54:14	MV: Everybody collected all their data. There are no fossils that need to be measured? .... I want the data sheet inside the sample bags because the next time we meet, we are going to put the information into the computer. And who will that information go to? Miss S. She's going to analyze it.			
		0:55:27	MV: At this time, Renee, do you want to go pick up the rulers?			
			Can I pick up magnifying glasses?			
			MV: I think some people still need them for notes.			
			MV: Where are your notes, Raul? You don't even have your book open.			
			MV: At this time, the recorder from each group the the sample bags...			

		0:57:37	MV: Everybody has samples over at table, all the... I need Miguel and Matias to collect magnifying glasses. I need all the desks back together.			
			[Classroom shifting; tables moving; where's the empty/missing desk?]			
		1:02:24	MV: How many people still have not finished their graphic organizers for their Tricky Tracks story? The setting, characters... If it's not complete, get it out now.			
			[Reorganization]			
		1:03:50	Some people are getting confused between a graphic organizer and a rough draft. What is that? Raise that up..			
			.... (some exchange) That's where you get the parts of your story... it's a starter, the foundation			
			Can your story change as you're writing it? Yes!			
		1:06:31	[MV with book]			
			MV: Who do we know that's on the hunt for a big fossil? Who do we know?			
			[Hands go up]			
			MV: What is the name of the text? I know Brenden knows			
			MV: And, the man is on the hunt for a man eating fossil.			
			Brenden: The book is called "Fossil Fever" [MV: Fossil Fever!]			
			MV: So this would be a text to text, right? You can make a text to text connection? [Shows image] Raise your hand if you think you know what this is. Carolina.			
			Carolina: A trilobite.			
			MV: Yep, it's a trilobite! [Starts reading book to students] 500 million years old! Is that old?			
			Students: Yes			
			MV: [Continues reading] And, the rock you've been examining is shale. You're finding your fossils in shale [continues reading] Can fossils be found everywhere in the United States?			
			Students: Yes			
			MV: Sounds like it, pretty much so. And there are specific fossils found in different parts of the US [continues reading... looking for signs of sea that was once here].			
		1:09:16	And that was a discovery that Raul made yesterday, that NYS was...		*	*
			Raul: Underwater		*	*
			MV: One time, underwater		*	*
			Pull out books and put post-it notes if you find anything interesting that you want to share. If did not finish graphic organizers you will be in during lunch.			
12/12	MV20	Verifying	(Duration: 28:11)			
			[MV opening bag of fossil in the back of the classroom to review with Group 2]			
			MV: Raul and Renee			
			We're going to go through you data and check if it's correct so that we can put it into the computer today.			
			Did you have any rocks that didn't have any fossils in them?			

			When you find some, move on; let me know what it is so that we can double-check the data. Okay, you found a brachio there? What's the measurement? What is that, is that a brachio, too? [MV takes rock from Raul] Yep, you're right.			
		0:01:34	What is this? Did you guys get that? Let me see. [MV using magnifying lens] I can't see anything. Is that anything there?			
			Raul: It doesn't look like it			
			It's just rock? Is that something?...			
		0:02:16	[MV returns rock; Renee and Raul measuring rocks]			
		0:02:45	Raul: Thirty-five?			
			MV: Good, you might be right but we don't have that measurement anyways. Can you go back to what you just measured?			
			Raul: I thjnk this was a shell or something.			
			MV: I know... oh, I see what you're saying. It's not here?			
		0:03:36	We're doing double-checking. We might be off so that's what scientists do, they double check.		x	
			MV: Where are you getting 30?			
			Raul: cause it stops right there.			
			MV: Where does it stop; put your finger where it stops			
			Raul: 35			
			MV: Okay, so we're going to switch this to 35...			
			Raul: 28			
			MV: 28, do you agree with him [to Renee]. Cause the longest is 25 [on the sheet]			
			Renee: 25			
			MV: 25, so we'll leave that. So this one's done. See, we're checking off our list, okay? Now, let's go to the brachiopod.			
		0:06:00	[Raul gets shells to model measuring the fossils]			
			MV: Which way do we measure the length?			
			How do we see the ridges going there? Which way is up? Alright, maybe that's not a good description. But, do length. Which way are the lines going?...		*	
			Length is this way, the first way you showed me. If the ridges are going this way, which way is length?			
		0:08:00	So, according to your ridges, which way is length? [Raul demonstrates]			
			Ah....now how were you doing it the first time? [Raul shows] Now do you see the difference?...			
			Now try width, width would be the opposite. Ahora, so it is the flip. See how we have to fix our data. This is a good teaching moment for him, learning moment for me. [Raul's mom comes to pick him up; MV introduces R; gets up to give homework to Raul; Renee still sitting at table]			
		0:11:46	MV: Okay, are there any more fossils on this one, Renee?			
		0:12:34	...we did this one already. Is Alisa here? Alisa, come here and join Renee. You were in charge of measuring, right? You're identification? Where's Nelia? Okay, come on Nelia.			
		0:13:59	We're going to go through all the rocks; Did you find anything here?			
			Girls: Yeah			

			MV: Okay, what was that?			
			Nelia: A clam?			
			Renee: It is.			
			Alisa: I think it looked like a this [picks up clam shell]			
			MV: A clam? Okay, let's go to the clams. .... Let's check the measurement. Which way is that, length or width?			
			20 and 25? We might not have that one, now, what's the coloration?			
			Girls: Two.			
			MV: We all agree, 2? And what would be the fragmentation?			
			... is there anything else on that one?			
		0:16:01	[MV reflective to me: I think this is taking longer than I thought. So, we're going to go over all the information. But then we're not going to have a presentation....show the charts. We can show what Tim's class' data looks like]			
		0:17:30	MV: What did you find?			
			Alissa: Um, a brachiopod			
			Renee: Fragmentation of a brachiopod			
			MV: Let me see; your eyes are better than Miss V's. What makes you think it's a brachiopod? Look at your identification chart.... What do you think, R? I'm thinking it might have three, I don't know			
			R: I think it's a brachiopod, too.			
			MV: My eyes are bad, Miss V's eyes are bad. I have to get my glasses. That would help!			
			R: I want to ask the girls; why do you thought it was a brachiopod?			
			Alissa: Cause, like right here it's like this and like that			
			Renee: It's fragmentation			
			R: It's fragmentation? But why... how do you know it's not a clam?			
			[students learning in; shifting papers] Nelia: It doesn't look like it.			
			Renee: A clam goes like this... and I think it would be like this...			
			R: Okay			
			Renee: You can see the half of the heart			
			R: Okay, I think that's a great reason			
			Renee: See, like this part is shaped like this part right here. [demonstrating] And this part is like half of the symmetrical shape of the brachiopod.			
			R: And you all agree, or do you disagree?			
		0:19:53	Girls: We all agree			
			R: Where there any fossils that you disagreed about?			
			[Alissa showing] R: That one, you weren't sure about?			
			MV: Deme ver (let me see) [from a distance]			
			[MV comes back wearing glasses, laughing, students laugh]			
		0:20:18	MV: Let's see, what it this one that we were talking about? Over here, right? Hmmm...			
			Renee: I think it was the half of the brachiopod			

			R [to MV]: so they gave reasons for why they thought; [to girls] what kind of evidence do you have?			
			MV: where's it symmetrical; oh, I see what you're talking about. Maybe because it goes like that in.			
			Alissa [to Renee]: You measured that one, that little one?			
			Renee: no.			
		0:21:18	Okay, so you think it's a... we've decided it's a brachiopod [Alissa passes rock to Renee: Measure it.]...			
			Renee: 10			
			MV: 10? Dame ver			
			[Passes rock over] Okay, you're right, you're right.			
			MV: Let Nelia double check.			
			Nelia: Six			
			MV: Do you agree? Everyone? Happy? And what is the coloration?			
			Renee: 1			
			MV: Everyone agree? And fragmentation?....			
		0:23:56	Alissa [looking down at rock]: It's like 13-14			
			MV: Which way is that, width or length?			
			Renee: ... it's like this			
			[...very similar to previous episode]			
			MV: Okay, anything else on that rock?			
			Alissa: The teacher told me what it was. But, I forgot. She told me...			
			MV: What was this			
			Renee: Oh, it was a trilobite, I think!			
			MV: That's a trilobite? Oh, that's a crinoid? What it a horn-coral?			
		0:25:30	Alissa: It was in the little paper... [gets up to go get it]			
			R: Let's see... that one looks different, doesn't it?			
		0:26:15	[MV directing class from seat; Norma, you can create a vocabulary chart if you want....direct translations from the books you read; the word in English and the word in Spanish]			
		0:26:35	[Alissa comes back with chart]			
			MV: Okay, which one was it?			
			Alissa: She told me it was this one			
			MV: Okay, that's a clam			
			Renee: Clam?			
			MV: That's what I thought, it didn't look like a crinoid.			
		0:26:55	R: Alissa, who told you it was that one?			
			Alissa: The scientist			
			[further figuring out the rock, measurements, coloration, fragmentation]			
12/15	MV2	Data Rev	Tape Duration (48:10)			
			[MV sets up table in back of room to review fossil data with Group 2 again]			
		0:02:51	[Raul shows up and sits down]			
			MV: see if you find anything in that			



		0:03:23	You found something? Let me see			
			How can you tell it's a brachiopod? How can you tell this is not a clam?			
			Raul: It has ridges			
			MV: It does, so how would you be able to tell the difference. They both have ridges			
			Raul: It kind of looks like this part-- it goes up and then down?			
			MV: Would the be a good example of fragmentation representing brachiopod? No, because really, you can't tell it's a shell or a brachiopod. You can't really tell which one it is. It's just a piece like that. That's what I was trying to get you to see.			
		0:05:36	MV: Okay, measure it.			
			[Raul measuring, MV measuring]			
			[MV goes to get glasses]...			
		0:10:05	MV: Okay, check that one			
			Raul: inaudible [passes rock over to MV]			
			MV: It's probably just an indentation too small to see			
			Raul: Here check it, it's a clam			
			MV: It's just like the rock fell apart. You see anything... Found something?			
			R: Oh, let's see. Good job! You want to go wash that out?			
			[MV & R talk; do students make a lot of mistakes; no, actually pretty good; measurements are pretty good and they're comfortable deciding on the fragmentation and coloration; we're going to enter this data today]			
			[Interaction between Raul & MV; observing fossils, icecream social]			
		0:15:22	MV: I'm trying to think, R, what do you think this is?			
			[R gets up; observes fossil]			
			R: It's very fine			
			MV: I'm wondering because the ridges are very close together			
			R: Well, I heard Raul say that he thought it was supposed to be this one.			
			MV: Are the ridges supposed to be so close together			
			R: Well, I think he may be right on that because look, not only do they all come together but is it more than just the shape of a clam or brachiopod. It doesn't stop like a clam or a brachiopod; it goes around.			
			MV: Actually, you did find it then because you guys did decide that. It's probably your horn coral. And then I think Tish... Miss S... she did tell you she checked and said you had horn coral.			
		0:16:29	Raul: Oh, yeah! [enthusiastically]			
			MV: Now look around, is this still part of the horn coral, R? Did you see it Raul?			
			Raul: inaudible			
			MV: Okay, so that's probably a clam?			
			Let's measure our horn coral [Raul measuring]			

			MV: Don't go with this because we're double checking. Because this says it's 23 doesn't mean it's 23. We have to double-check.... alright, we want this way... no yawning... alright, here's your 23... What did you get, do you remember?			
		0:19:09	Raul: 19			
			MV: Yep, I agree with you, 19; so this one's correct			
			They had coloration 1; do you agree?			
			Raul: Yeah			
			MV: And, fragmentation what would it be?			
			Raul: I don't know it's...			
			MV: one through five what would it be?			
			Raul: A three, a two			
			MV: I'm going to go with a two, too.			
			Raul: If you look at it now, it looks like the pieces go around			
			MV: But the ridges are very close together. Now you found other stuff.			
		0:20:19	Raul: A clam			
			MV: Okay, show me			
			Raul: right here.			
			[R, MV, and Raul discuss the hard-to-identify sample]			
		0:24:10	[R leaves; MV and Raul continue to discuss fossil samples and measurements...]			
		0:29:06	MV: Anything else on any of the other rocks, Raul?			
			Raul: The... looks like the head of a trilobite [picks up rock and observes]			
			MV: Nelia come over here and Alissa...			
		0:30:53	MV: Do you see anything in here? In any of these two? It doesn't look like a coral to you?			
		0:31:03	Raul: The lines are um, real close together			
			MV: But remember we said that we'd see what the group had to say?			
			Anything else on that rock that we need to report? Here, Alissa. Are there any more?	*		*
			Alissa: Look at that			
			MV: What do you think it is?			
			Alissa: A clam?			
			MV: I think that's what you said too, right Raul?			
			... [students dicussing] Raul: looks like a piece of brachiopod			
		0:32:50	MV: Is that the same one you already measured? [girls shake heads no]			
			... Nelia: 5; MV: is that the length or width...			
			MV: Clam or brachiopod; Students: A brachiopod			
			[fragmentation; coloration discussion; student consensus]			
		0:34:31	MV: Okay, we're done with that one. Put it in the bag			
			[Students observing rock; discussing measurements; barely audible]			
		0:36:30	Alissa: This the the width			x
			Raul: This is width [gestures] this is length [gestures]			x

			MV: No no no, you got it confused. [MV draws]			
			Raul: ohhhhh			
			MV: That's okay, when you're used to length, we look this way...			
		0:37:24	MV: Okay, what do we have?			
			Raul: A clam			
			MV: A clam? And the length?			
			Group: 14			
			MV: and the width?			
			Group: 15			
		0:37:48	MV: And, what's the coloration and fragment..?			
			Raul: Three			
			MV: Three?			
			Raul: From three down			
			MV: And, what's the fragmentation?			
			Raul: It looks like a 2			
			MV: What do you guys decide? You have to decide as a group	*	*	
			...			
			MV: Are we done with that rock or is there more?			
			Students: There's more			
			Raul: Yeah, there's a brachiopod in there...			*
		0:39:39	[Alissa is reviewing LxW with MV; Renee approaches group]			
		0:39:55	[MV to Renee; Have a seat, honey]			*
			Raul: [singing] sientate...			
			[continued discussion of fossil size, fragmentation, coloration, and reaching student agreement for data to be entered]			
		0:44:31	MV: Where do you see a crinoid here? [Renee gets up and approaches MV] A crinoid should be a long skinny line. That's just an indentation. Where do you see it?			
		0:44:47	Raul: This right here [pointing with ruler's corner]			
			Alissa: Let me see [but Raul passes fossil to MV; MV passes to Renee]			
			MV [to Renee]: Double check it. ... I know, but let everybody else see it too. There aren't any ridges or little lines...	*		
		0:45:29	[Alissa and Nelia discussing in Spanish]			*
		0:46:37	MV: It's not a crinoid, but good try, Raul. Good try, it's not a crinoid [laugh]. It might not be anything.			
			Alissa: No, not the line, not the line....there's something... (else?)			
		0:47:00	[Still discussing fossil that they are not sure about. Run out of time]		*	

## APPENDIX D

### Video Data Collection Procedures

#### Narrative Account of Video Data Collection

Video recording was one of many components of data collection I used in this dissertation research study. While other forms of data include fieldnotes, student journals and work samples, interviews, and pre-post measures, I used video recordings to capture how two teachers implemented an instructional unit and to what extent students were engaged in the activities. This narrative account describes how I collected video data for this project. The purpose of this account is to describe the nature of the video data and better frame the possibilities and limitations of these data in relation to other forms of data for addressing my research questions.

I ran into multiple challenges during the video-data collection phases of this work. From a technical perspective, I was limited to the use of one camera. Further, the camera did not have a wide-angle lens. This means that when I chose to zoom in or pan the scope of the camera's lens around the room, I was introducing selection into my video data. As Hall (1998) describes, during these moments, other possibly important interactions were effectively lost. Additionally, I did not have the appropriate equipment to selectively channel audio recording. Thus, video sound is based on what the camera's microphone was able to pick up. As a result, most informal conversations and student group work were not captured.

Another challenge was related to negotiating my positionality within the class. Our project team elected to use a participant-observer approach to our data collection, based on the relationships we had already established with the participating teachers during a professional development program over the previous summer. This translated into moments where the teachers called on me to answer questions, work with students, and even teach. During these times, I was not able to gather fieldnotes or control the video-camera. Any resultant record during these moments is limited to videotape. However, it is possible that at times, these activities moved out of the screen of the recording camera and were only captured by the camera's microphone.

I officially began data collection in Monica's 5<sup>th</sup> grade classroom on September 30<sup>th</sup>, 2008. I will describe her classroom setting in more detail to contextualize video-data collection.

#### *Monica's 5<sup>th</sup> Grade Classroom*

Monica teaches science in a 5<sup>th</sup> grade urban dual-language (Spanish) classroom, where about a third of the students are English language learners. She shares her class with Sra. Lucas, who focuses on Spanish language arts, social studies, and math instruction with the same group of children. Because Monica's position is focused on teaching English language arts, science, and health, she mostly teaches in English. This past fall, Monica implemented the Fossil Finders (FF) project on Monday through Wednesday mornings as part of her 60-90 minutes of instructional time allotted for science per week. She was able to extend the amount of time focused on science by integrating math and language arts into the instructional unit. However,

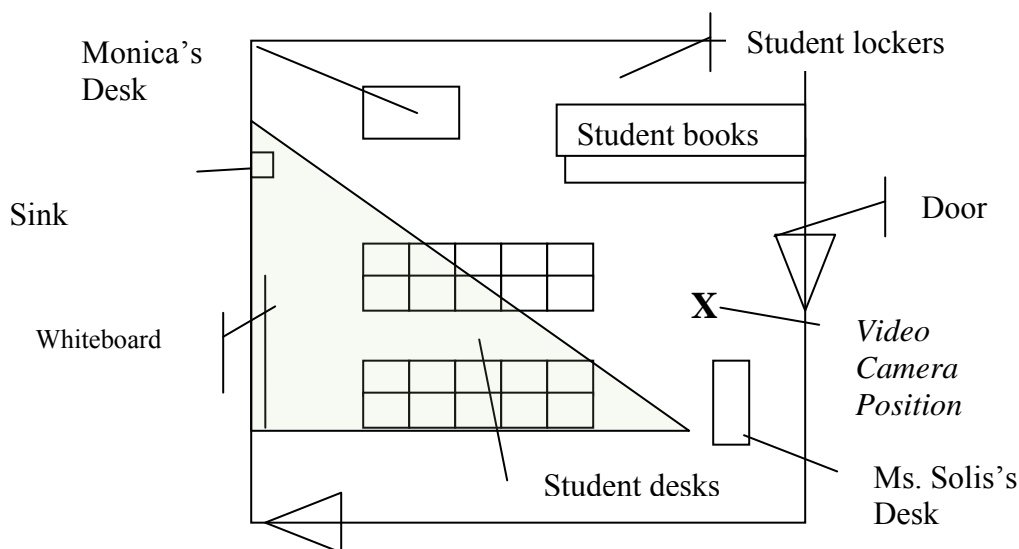
her instructional time was even further divided. During the first hour of science instruction, more than half of Monica's students were taken out of class for English as a second language (ESOL) instruction. Monica designated the group of eight remaining students as "Fossil Finder Leaders" and piloted the Fossil Finders instruction with this group. This differentiation may have led to other classroom dynamics that play out in group situations, as these students were later divided across four larger groups in the classroom and instructed to help their peers learn about and complete the tasks. Two of the Fossil Finder Leaders became focus students that I later interviewed about their views on science. These unique classroom features possibly influence the amount of instructional time each student had, the self-efficacy of particular students, and the overall classroom dynamics.

Given Monica's schedule for instructional time in science, the Fossil Finders unit stretched over the course of the semester. Monica began the unit with Tricky Tracks instruction in late September, where students learned about observations, inferences, and nature of science. Based on this activity, Monica's students wrote their own stories about what they thought had happened. In this way, Monica integrated science learning with a literacy and language development activity. Monica also found that for students to be able to measure fossil samples, they would need to learn the metric system. In preparation, she embedded a mini-instructional unit into the Fossil Finders project related to measurement in October. Monica brought meal worms into her classroom and had students observe them and take measurements. Students wrote reports about their mealworms and presented them as a final component of this sub-unit. In mid-November, the Fossil Finders instructional unit was resumed with students finishing and presenting the Tricky Tracks stories, learning to identify different kinds of fossils, and measuring fossils. During the centerpiece of the instructional unit, the investigation, students handled, identified, and measured an authentic set of fossils over a three day period in December, following a class session in which they interacted with a practicing paleontologist.

The spatial arrangement of Monica's classroom introduced some challenges to video-recording. Monica's school was hosted in a temporary building this year, while the permanent location was being remodeled. The temporary building is an old factory building with rooms constraining traditional classroom settings. For example, Monica's classroom has two doors and no windows. Student desks are lined up into two long tables made up of 10 individual desks in rows facing each other. The other portion of the room holds student lockers and a carpeted reading space lined with bookshelves.

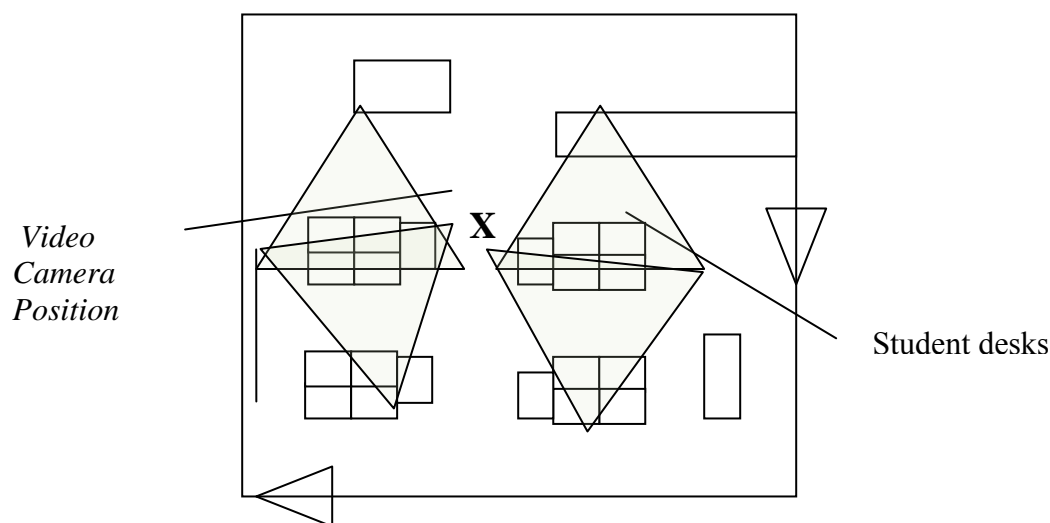
Videotaping challenges included setting up a space for the camera. I found that I was able to capture Monica's instruction from directly next to Ms. Solis's desk (See Figure A1). However, from this angle, I was only able to capture half of the students' faces as they were seated facing each other. Moreover, I was not able to capture student interactions and engagement with the instruction materials, such as fossils. In an attempt to work within these limitations early on in the study, I found moments of opportunity in moving around the room with the camera and interviewing individual students about what they were seeing. I later questioned the intrusiveness of this approach: to what extent did I distract students from what they were doing with

my questions? Certain students were taken aback by the camera and I negotiated to videotape only the fossils they were looking at while they were talking. Other students began to approach the camera to show what they were finding. Students were aware of the fact that I was there to learn about how the curriculum was going and that I wanted to learn more about what they were seeing. However, I was surprised by the extent to which they had integrated me into the activities related to the Fossil Finders curriculum. I assume that I began representing the fossil-based science instruction.



**Figure A1. Monica's Regular Classroom Configuration**

When students were working in their Fossil Finders Teams, desks in the classroom were rearranged into four groups (see Figure A2). During this portion of instruction, I was able to place the camera in a stationary location and capture each group (of 4-5 students) individually. To do this, I rotated the camera around the room to capture some of the interaction at each of the groups. I moved the camera from group to group when student voices and body language indicated that they were engaged in the activity. The camera shifting was not consistent, however, as there were times that I was working with particular groups and was not able to evaluate other groups. In an effort to better gauge student thinking, I approached groups with questions about what they were seeing and videotaped these interactions. In this case, I am better able to evaluate students thinking; however, my presence and questions also influence the regular interactions within and between groups. There were also times where Monica worked with a group of students at her desk. Because the study focused on the nature of her instruction, the camera was placed by her desk during these times. A second camera would have been instrumental in capturing what was occurring in the rest of the classroom during this time.



**Figure A2. Monica's Classroom Configuration during Group Work**

On a daily basis, the duration of video-recording in Monica's classroom spanned the course of around 2 hours. It typically began at around 9:35 am and concluded at around 11:30. Students took a bathroom break at around 10:30 on a daily basis. During this time, I inserted a new Mini-DV tape into the camera. The camera was set up on a tripod that I would leave in the classroom.

My field journal included general observations of the classroom as well as exchanges between the teacher and her students. I generally kept track of time things were noted according to the video camera "tape time," or minutes into the recording. These time cues provided a useful tool for compiling a video-content log of the unit and to pulling out instances for further analysis. Though "important moments" are somewhat confounded with various episodes of zooming in and out on groups and individual students, the video recordings can serve a useful function for reconstructing some of the occurrences in the classroom during the Fossil Finders unit. These occurrences provide a record of the nature of instruction and its change over the duration of the unit. Moreover, the video recordings provide data on moments in which culturally congruent and inquiry-based instructional approaches are instantiated and how students respond. For example, video footage is illustrative of students being on-task and engaged in the curriculum. These data can be helpful for determining the classroom culture and the extent to which the teacher uses these instructional approaches.

## APPENDIX E

### **Instructional Congruency Framework and Rubric from Luykx and Lee (2007)**

#### **1. Diversity of Cultural Experiences and Materials**

*To what extent does the teacher integrate students' cultural experiences and materials in instruction?*

Most often, “normal” classroom instruction reflects the cultural experiences and artifacts of the dominant ethnolinguistic group. This scale measures the extent to which teachers incorporate and accommodate cultural experiences and materials that students from other groups bring to the class. To provide effective instruction for students from diverse backgrounds, teachers need to articulate student experiences with the nature and content of science.

Ideally, teachers should have knowledge of students' lives at home and in the community. They should be able to draw upon materials and community resources (e.g., people with relevant knowledge and skills, places, institutions) that reflect the cultural diversity of their students, use culturally relevant examples and analogies drawn from students' lives, and consider instructional topics from diverse cultural perspectives. Note: Teachers may use cultural analogies or examples from the mainstream culture that would likely be incomprehensible to students from non-mainstream backgrounds. These episodes are not considered in this scale, which is designed to measure teachers' incorporation of elements from cultures that are traditionally underrepresented in science classrooms. However, observers should describe these episodes in observation notes.

*The scoring rubric for this scale is as follows:*

1. The teacher does not use or mention diverse cultural experiences or materials in instruction.
2. The teacher mentions different cultural experiences and materials, but does not incorporate them as part of instruction.
3. The teacher uses a few (one or two) examples of diverse cultural experiences and materials, and incorporates them as part of instruction.
4. The teacher uses cultural experiences and materials of diverse origins, and incorporates them as important in instruction. The teacher encourages students to share their own cultural experiences and materials.
5. The teacher incorporates a variety of cultural experiences and materials into classroom instruction. Students volunteer to share cultural experiences and materials.



## **2. Students' Home Language in Regular (Non-Bilingual) Classrooms**

*To what extent does the teacher use students' home language to enhance understanding in regular (non-bilingual) classrooms?*

Students from diverse language backgrounds may bring knowledge of their home languages to the classroom. This scale indicates the extent to which teachers use students' home language in regular (non-bilingual) science instruction, and/or encourage students to use their home language. Teachers may use students' home language as appropriate to enhance the students' understanding of instruction in regular (non-bilingual) classrooms. Even with students who are English proficient, teachers may use key terms in students' home language to promote understanding (e.g., “vapor” in Spanish in a lesson on water vapor and evaporation). Teachers may support and encourage students to use their home language among themselves to enhance understanding and construct meanings. Teachers may also encourage more fully bilingual students to assist less English-proficient students in their home language. Class descriptions should note if teachers are using the translations of key science terms provided in the units. Note: Teachers may use students' home language for management purposes (e.g., to reprimand students for inattention or disruptive behavior). This differs from the use of the language for instructional purposes and thus does not count for ratings.

*The scoring rubric for this scale is as follows:*

NA: All (or almost all) students in the class are monolingual English speakers; OR it is a bilingual classroom.<sup>9</sup>

1. The teacher does not use students' home language in instruction, and does not allow or invite students to use their home language.
2. The teacher does not use students' home language in instruction, but invites a few students (10% or less) to use their home language a few times (10% or less); OR the teacher uses the home language very minimally, but does not encourage students to do so.
3. The teacher uses students' home language in instruction minimally or not at all; however, the teacher, some of the time (10–20%), invites students to use their home language, or encourages more fully bilingual students to assist less English-proficient students in their home language; OR the teacher uses the home language some of the time (10–20%), but does not encourage students to do so.

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<sup>9</sup> In a personal conversation, Okhee Lee and I discussed how this framework can be applicable toward understanding and measuring best teaching practices in any classroom. Thus, this framework was used in a dual-language classroom setting.

4. The teacher uses students' home language in instruction a few times (10% or less). In addition, the teacher, some of the time (10–20%), invites students to use their home language or encourages more English-proficient students to assist less English-proficient students.

5. The teacher uses students' home language for instructional (not classroom management) purposes some of the time (10–20%). In addition, the teacher, much of the time (20–50%), invites students to use their home language or encourages more fully bilingual students to assist less English-proficient students in their home language.

### **3. Scientific Authority**

*To what extent is the authority for determining the validity of a scientific argument or answer shared by students and teacher?*

This scale determines the extent to which the lesson supports a shared sense of authority and responsibility for validating students' scientific reasoning. When students take on responsibility for justifying their own reasoning, they develop stronger understandings of the content and are more likely to make meaningful connections across disciplinary content and/or to the real world. To score high on this scale, the teacher and students hold each other accountable for convincing themselves and each other that their reasoning is sound and that their answers are correct. Low scores are given either when the authority for determining whether something is right or wrong rests with the teacher or the text, or (as occasionally happens) when neither the teacher nor students have a means for determining whether their reasoning is scientifically valid or not. This scale is not intended to measure students' control over the content of a lesson. The teacher still must decide what is worthwhile science and when a particular activity is not worth exploring in all of its details. In other words, the teacher makes a curricular decision, but those decisions should not undermine the sharing of scientific authority within the class.

*The scoring rubric for this scale is as follows:*

1. For the most part, students rely on the teacher and/or text as the sole legitimate sources of scientific authority. Students accept an answer as correct only if the teacher says it is correct or if it is found in the book, and seldom challenge information from either of these sources. If stuck on a problem, students almost always ask the teacher for help; OR there is no clear authority for determining whether someone's scientific reasoning is valid. The teacher does not indicate whether students' answers are right or wrong, becomes flustered when queried about a topic, or is at a loss as to how to find out the answer, instead of suggesting possible resources to students.

2. Students rely on the teacher and some of their more capable peers as the legitimate source of scientific authority. The teacher often relies on a few students (who are clearly recognized as being better in science) to provide the right answer when pacing

the lesson, or to correct an erroneous answer. As a result, other students often rely on these students for correct solutions, verification of right answers, or help when stuck.

3. Many students (20–50%) share scientific authority among themselves. They tend to rely on the soundness of their own scientific arguments for verification of an answer. However, they still look to the teacher as the authority for making final decisions. The teacher sometimes asks students to provide their own arguments or hypotheses (e.g., by asking them, “What do you think?” or “How do you know?”), but intervenes with the answer in an effort to speed things up when students seem to be getting bogged down in the details of an argument.

4. Most students (50–90%) share in the scientific authority of the class. Although the teacher might intervene when students are getting bogged down, she usually does so with a question that focuses their attention or helps them to see a contradiction that they were missing. The teacher often answers a question with a question, although from time to time she provides the students with an answer.

5. Almost all students (90% or more) share in the scientific authority for the class. Students rely on the soundness of their own arguments and reasoning. As a rule, the teacher answers a question with a question or provides instrumental help (as opposed to just giving the answer) for students to make their own decisions. It is not uncommon to see students leaving a class still arguing about one or more scientific points in their lesson.

#### **4. Linguistic Scaffolding to Enhance Meaning**

*To what extent does the teacher tailor his or her verbal communication (in English) to enhance students’ understanding?*

This scale is designed to measure the extent to which teachers provide linguistic scaffolding to enhance students’ comprehension of academic content. Linguistic scaffolding refers to how teachers adjust the level and mode of their communication to enhance students’ comprehension. With effective linguistic scaffolding, teachers communicate at and slightly above students’ level of linguistic competence to promote comprehension of the lesson. Teachers may also structure classroom environments in such a way as to encourage students to provide linguistic scaffolding for their peers. Note: There may be a wide range of levels of English proficiency, as well as familiarity with scientific terminology, within a single classroom. The scale refers to the teacher’s adaptation of his or her use of language to address all of these levels, not just one (be it the highest or the lowest). First, teachers recognize the diversity of students’ levels of language proficiency, appropriately structure activities to reduce the language load required for participation, and use language that matches students’ levels of communicative competence in length, complexity, and abstraction. Teachers who fail to adequately adjust their verbal communication to students’ level may regularly communicate at a level beyond some students’ comprehension. Conversely, teachers may consistently “lower the bar” to accommodate the least proficient

students, communicating at levels that fail to challenge other students or help increase their level of competence. Teachers may paraphrase the same idea in different ways, helping students' comprehension in some settings but confusing the students in other settings.

Second, ideally, teachers communicate at and slightly above their students' level of communication. For example, during a lesson that involves the concepts of "increase" and "decrease," a teacher in a class with many English language learners (ELLs) helps them understand by also using the terms "go up" and "go down," hand gestures, or even a drawing. In another class, where students are more English proficient, a teacher asks the class to give scientific words, such as "expand" and "contract." In both classes, the teachers are promoting English language proficiency, while helping their students to understand scientific concepts. Third, teachers build students' understanding and discourse skills by providing linguistic scaffolding. For example, when a student responds, "it condenses," a teacher asks the student to clarify what "it" refers to, and the student responds, "water vapor condenses." The teacher extends the response by asking, "water vapor condenses into what?" Gradually, the teacher builds the understanding, "water vapor condenses into little water drops on a cold surface." Finally, teachers may also use ESOL strategies with ELLs, including:

- nonverbal gestures, total physical response, modeling, and demonstration to explain
- difficult concepts;
- peer tutoring among students;
- transition from concrete to abstract thinking or ideas;
- reduction of difficult language to essential vocabulary or shorter, simplified utterances; multiple modes of representation using nonverbal, oral, graphic, and written communication; and
- use of realia (demonstration of real objects or events).

*The scoring rubric for this scale is as follows:*

1. The teacher does not communicate at the appropriate level and mode of language to enhance students' comprehension (the level of communication is either too high or too low, or is not varied to accommodate students with different levels of proficiency).
2. The teacher rarely communicates at the appropriate level and mode of language to enhance students' comprehension. The teacher provides linguistic scaffolding with a few students (10% or less) a few times.
3. There is at least one significant activity or event in which the teacher communicates at and slightly above students' level of communication, either with small groups of students (10–20%) or with the whole class.
4. The teacher, much of the time (20–50%), communicates at and slightly above students' level of communication. He/she uses at least two different types of scaffolding (verbal, gestural, written, graphic). Many students (20–50%), much of the

time (20–50%), demonstrate understanding of the teacher or the lesson. There may be some evidence of linguistic scaffolding among students for their peers.

5. The teacher, most of the time (50–90%), communicates at and slightly above students' level of communication. He/she uses a variety of communicative modalities (verbal, gestural, written, graphic) to provide scaffolding for students throughout the lesson. Most students (50–90%), most of the time (50–90%), demonstrate understanding of the teacher or the lesson. Students are observed to provide linguistic scaffolding for their peers.

Rubric for Classroom Observations of Instructional Congruency;  
Adapted from Lyukx & Lee, 2007

Day: Date:	Score /Rationale	1	2	3	4	5
<b>Diversity of Cultural Experiences and Materials</b> To what extent does the teacher integrate students' cultural experiences and materials in instruction?						
<b>Scientific Authority</b> To what extent is the authority for determining the validity of a scientific argument or answer shared by students and teacher?						
<b>Students' Home Language in Regular (Non-Bilingual) Classrooms</b> To what extent does the teacher use students' home language to enhance understanding in regular (non-bilingual) classrooms?						
<b>Linguistic Scaffolding to Enhance Meaning</b> To what extent does the teacher tailor his or her verbal communication (in English) to enhance students' understanding?						

## **APPENDIX F**

### **Fossil Finder Pre-Post Content-Matter Assessment**



## Student Questionnaire

1. The **first letter** of your **FIRST** name is:

Example: My first name is Chris

Answer here:

2. The **first letter** of your **LAST** name is:

Example: My last name is Smith

Answer here:

3. Your **date of birth** is:

Example:   /   /    
Month Day Year

Answer here:

/  /   
Month Day Year

4. What **grade level** are you in right now? (Circle One).

5   6   7   8   9   10   11   12

5. I am a: (Check one box only)

☐ Female

☐ Male

6. My **background** is best described as: (Check one box only)

☐ African American.

☐ Hispanic/Latino(a).

☐ Native American/Alaskan Native.

☐ White (not Hispanic/Latino(a)).

☐ Asian or Pacific Islander.

☐ Other \_\_\_\_\_

**Part I.**

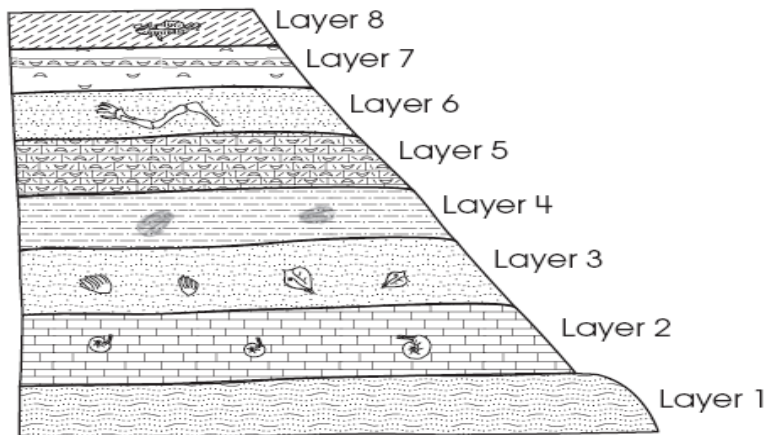
Please read each question carefully and chose the best answer by circling the letter next to your answer choice. This is not a test and it will not be graded.

1. Corals are animals that live in tropical oceans. Fossils of corals are found in New York. What does the presence of coral fossils suggest about how the environment of New York has changed over time?

- A. New York was once covered by warm seas.
- B. A large glacier once passed over New York.
- C. The average rainfall in New York is now much more than it once was.
- D. The average temperature in New York is now much warmer than it once was.

**Use the information below to answer question 2.**

A paleontologist was studying the evidence of extinction of organisms in the fossil record. Data were collected at several work sites. The paleontologist developed the drawing below of eight layers at one work site. Based on observations, the paleontologist concluded that the layers had been undisturbed by geological activity.



2. Which layer should have the oldest fossils?

- A. layer 8
- B. layer 6
- C. layer 4
- D. layer 2



3. The fossils of dinosaurs that lived millions of years ago can be found in

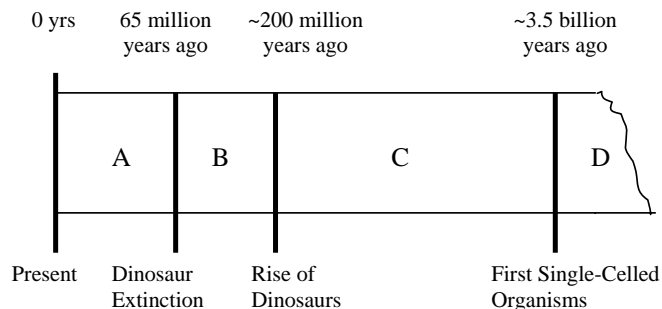
- A. the water of oceans
- B. the ice on ponds
- C. the trunks of trees
- D. rocks in the ground

4. Which is most likely to become a fossil?

- A. an imprint of a rock in mud or sand
- B. the remains of a past living organism buried in mud or sand
- C. an ancient building or arrowhead
- D. a mineral such as quartz

**Use the information below to answer question 5.**

Below is a portion of a geologic time line. Letters A through D represent the time intervals between the labeled events, as estimated by scientists.



5. Fossil evidence indicates that trilobites and brachiopods lived in central New York during which time interval?

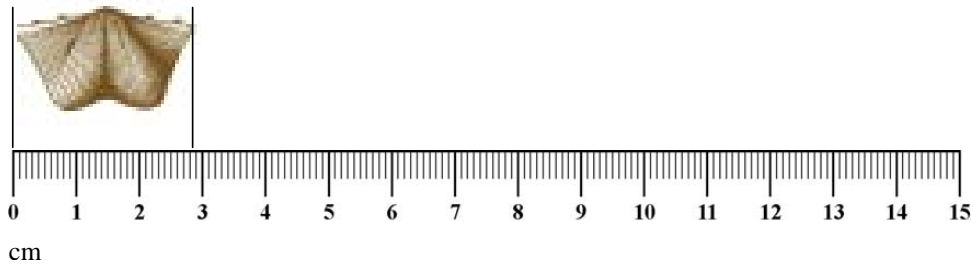
- A. Interval A
- B. Interval B
- C. Interval C
- D. Interval D

6. By examining fossils, scientists think that:

- A. All existing plants and animals have not changed since Earth formed.
- B. Plants have changed over time, but animals have not.
- C. Animals have changed over time, but plants have not.
- D. Many changes have occurred to plants and animals.

**Use the information below to answer question 7.**

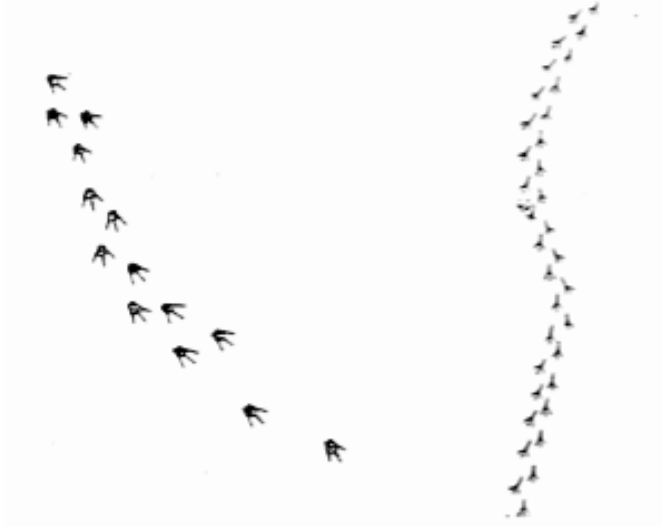
The picture below shows a brachiopod being measured by a student. The width of the brachiopod is shown between the two lines.



7. What is the width of the brachiopod?

- A. 2.8 mm
- B. 280 mm
- C. 28 mm
- D. 30 mm

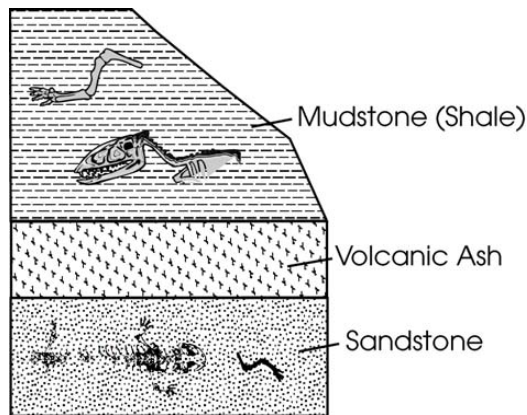
Use the picture below to answer question 8.



8. Which is an inference about the tracks above?

- A. One set of tracks is larger than the other.
- B. Both sets of tracks were made by animals.
- C. Each set of tracks has different spacing.
- D. Each set of tracks is a different shape.

Use the information below to answer question 9.



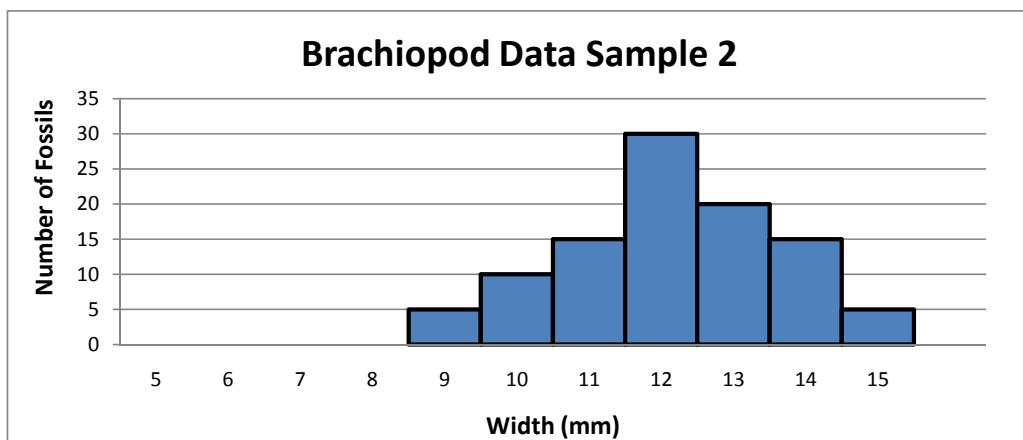
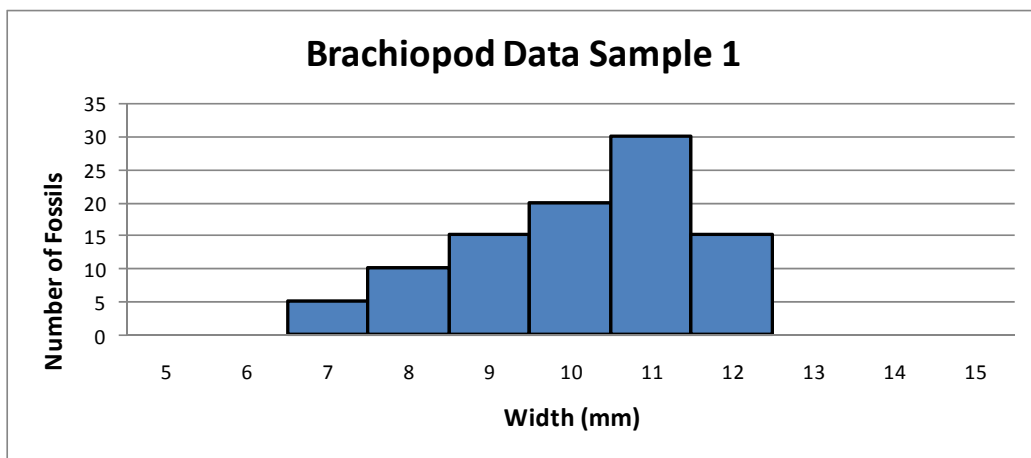
Scientists see three layers of rock exposed on the side of a hill. The bottom layer is sandstone with fossils of a certain species of reptile found only in this geographic location. The middle layer is volcanic ash. The top layer is mudstone (shale) with fossils of a different species of reptile.

9. The fossil evidence supports which hypothesis about the extinction of the older reptile species?
- A. The older reptile species went extinct because sea levels rose and flooded its habitat.
  - B. The older reptile species went extinct because a predator was introduced into the environment.
  - C. The older reptile species went extinct because it could not compete with the younger reptile species.
  - D. The older reptile species went extinct because a volcanic eruption caused the environment to change.

Use the information below to answer questions 10 through 14.

Students investigated samples of shale containing fossils. A group of students made observations and collected data from two samples of rock. The students measured and counted the brachiopod fossils they identified in each sample of rock. Data collected by the students are shown on the graphs below.

**Brachiopod**



10. How do the sizes of brachiopods in Sample 1 compare to the sizes of brachiopods in Sample 2?

- A. Sample 1 has more large brachiopod fossils.
- B. Sample 2 has more large brachiopod fossils.
- C. The range of fossil sizes in Sample1 and Sample 2 are the same.
- D. It is not possible to determine from the given data.

11. All students observed and measured their fossils in the same way. After doing this, the students recorded their measurements carefully in a data table. Which of the following is **not** important when performing scientific investigations?

- A. for all groups to have the same results when looking at different data.
- B. to accurately record fossil measurements in a data table.
- C. to follow the same procedure for measuring the fossils.
- D. to organize data so that it can be interpreted by others.

12. A student made the following statement after looking at the graphs. "The largest brachiopod fossil in Sample 2 is 11 mm wide." This statement is

- A. a correct inference
- B. an incorrect inference
- C. a correct observation
- D. an incorrect observation

**Use this information and the graphs above to answer questions 13 and 14.**

A teacher collected a rock sample from two places on the same cliff. The teacher tells the students that the rocks are of different ages. Brachiopods in Sample 1 are about 400 million years old. Brachiopods in Sample 2 are younger than those in Sample 1.

13. Based on this information and the graphs, what might students infer about these two samples of brachiopods?

- A. Environmental conditions may have changed causing brachiopods to become extinct.
- B. There are twice as many brachiopod fossils in Sample 1 as there are in Sample 2.
- C. Environmental conditions may have changed allowing brachiopods to grow larger.
- D. There are no brachiopods smaller than 5 mm in Sample 1 or in Sample 2.

14. Based on the teacher's information and the graphs, what evidence do students have that the brachiopod fossils in Sample 1 may be a different species than those found in Sample 2?

- A. There are more brachiopod fossils in Sample 1 than in Sample 2.
- B. The average size of fossils in Sample 2 is larger than the average size of fossils in Sample 1.
- C. Fossils in both samples are identical to each other.
- D. The largest fossil in Sample 2 is smaller than the largest fossil in Sample 1.

**Part II.                    *Views of the Nature of Science (VNOS-E)\****

Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.

Some questions have more than one part. Please make sure you put answers for each part.

This is not a test and it will not be graded. There are no “right” or “wrong” answers to the following questions.

If you need, you can draw pictures to explain your ideas.

\*Adapted with permission from: Views of Nature of Science Elementary School Version (VNOS-E)  
Lederman, J.S. & Lederman, N.G. (2005) Developing and Assessing Teachers' and Students' Understandings of Nature of Science and Scientific Inquiry. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Dallas, TX.



1. What is science?

2. (a) What are some of the other subjects you are learning?

(b) How is science different from these other subjects?

3. Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?

4. (a) How do scientists know that dinosaurs once lived on the earth?

(b) How sure are scientists about the way dinosaurs looked? Why?

5. A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists all have the same facts about dinosaurs, then why do you think they disagree about this?

6. (a) Do you think scientists use their imaginations when they do their work?

**Yes**

**No**

(b) If **No**, explain why?

(c) If **Yes**, then when do you think they use their imaginations?

**Content questions on this instrument were adapted and used with permission from the following sources:**

Question 1. Adapted from Ohio Achievement Test Grade 5, May 2008. Retrieved from:  
<http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEDetail.aspx?page=3&TopicRelationID=1070&ContentID=7479&Content=54218>

Question 2 Ohio Achievement Test Grade 8, May 2008. Retrieved from:  
<http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEDetail.aspx?page=3&TopicRelationID=1070&ContentID=7479&Content=54218>

Question 3 Trends in International Mathematics and Science Study (TIMSS) Grade 4 Science Test, 2003.  
Retrieved from: <http://nces.ed.gov/timss/educators.asp>

Question 4 Daniel K. Capps, Cornell University and Dr. Robert M. Ross, Paleontological Research Institution, Fossil Finders Project 2008

Question 5 Graphic and source material adapted from New York Regents Earth Science High School Examination, August 2001. Retrieved from: <http://www.nysedregents.org/testing/hsregents.html>

Question 6 Misconceptions Oriented Standards-based Assessment Resource for Teachers (MOSART) Earth Science Test: 5-8, form 821. Retrieved from: <http://www.cfa.harvard.edu/smgphp/mosart/index.html>

Question 7 Graphic and source material adapted from New York State Grade 8 Intermediate-level Science Test, June 2004. Retrieved from: <http://www.nysedregents.org/testing/hsregents.html>

Question 8 Graphic adapted from Project ICAN: <http://www.projectican.com/trickytracks.html> Item from Daniel K. Capps, Cornell University and Dr. Robert M. Ross, Paleontological Research Institution, Fossil Finders Project 2008

Question 9 Ohio Achievement Test Grade 8, May 2007. Retrieved from:  
<http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEDetail.aspx?page=3&TopicRelationID=1070&ContentID=7479&Content=54218>

Questions 10-14: Graphic and source material adapted from: Trends in International Mathematics and Science Study (TIMSS) Grade 8 Science Test, 2003. Retrieved from: <http://nces.ed.gov/timss/educators.asp>

**Nature of Science questions on this instrument were adapted and used with permission from:**

Judith S. Lederman & Norman G. Lederman. (2005). *Views of Nature of Science Elementary School Version (VNOS-E)*.

## APPENDIX G

### Views of Nature of Science Elementary School Version (VNOS-E)<sup>10</sup>

#### Views of Nature of Science Elementary School Version (VNOS-E):

##### Instructions

- Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.
- Some questions have more than one part. Please make sure you put answers for each part.
- This is not a test and will not be graded. There are no “right” or “wrong” answers to the following questions. I am only interested in your ideas relating to the following questions.
- If you need, you can draw pictures to explain your ideas.

1. What is science?

2. (a) What are some of the other subjects you are learning?

(b) How is science different from these other subjects?

3. Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?

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<sup>10</sup> Taken from: Lederman, J. S., and Ko, E. (2004). *Views of nature of science*, Form E. Unpublished paper. Illinois Institute of Technology, Chicago, IL.

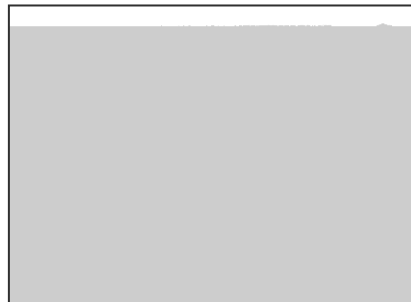
Components of the VNOS-E were included in the Fossil Finders Pre-post Content-Matter Assessment (See Appendix G).

4. (a) How do scientists know that dinosaurs once lived on the earth?

(b) How sure are scientists about the way dinosaurs looked? Why?

5. A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists all have the same facts about dinosaurs, why do you think they disagree about this?

6. TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help them make these pictures.



How certain do you think the weather people are about these pictures? Why?

7. (a) Do you think scientists use their imaginations when they do their work?

**Yes**

**No**

(b) If **No**, explain why?

(c) If **Yes**, then when do you think they use their imaginations?

## APPENDIX H

### Student Interview Protocols

Focus on students' sense of self (identity) and what and how they know (knowledge production, funds of knowledge) and views of science

	What I'm trying to get at	Academic Question	Rephrased Question
1	Background: Name	What is the student's name?	What is your name?
2	Background: Age	How old is the student?	How old are you?
3	Background: Grade-level	What grade is the student in?	What grade are you in?
4	Background: Ethnicity	Where is this student's family from?	Where is your family from?
5	Background: Ethnicity, Self-description (dynamic)	How does this student view himself/herself in general? How does this student view himself/herself in relation to the people in his/her community?	How would you describe yourself? How do you see yourself as similar or different from those in your community?*
6	Background: Language	What language/s does this student speak?	Do you speak another language? What language? If everyone spoke your language, what would you say?*
7	Funds of Knowledge and Identity	What kind of knowledge does the student value and identify with? What do they do? What do they consider themselves to do well?	What is something that you are really good at? Tell me about some of your hobbies and favorite things to do?*
8	Funds of Knowledge and Identity	What kind of knowledge does the student value and identify with? What do they do? What do they want to learn more about?	What do you know that is important to you? How did you learn it? Have you taught it to somebody else? What do you

			want to learn more about or get better at doing?*
9	Life-worlds and Schooling Divide (Borders/Boundaries)	How does the student view differences in life-world and school? Are differences evident (will science be mentioned)?	What do you feel are the similarities and differences between what you learn at home and what you learn in school?*
10	School learning environments (Instructional congruency)	What kind of learning environment does the student identify as being supportive to learning (are features of instructional congruency included)?	What are your favorite times and school and why? How do you feel in your favorite classrooms and with your favorite teachers, and why?*
11	Student personal goals and aspirations; Views on the value of schooling	What does the student aspire to be? Does the student think that schooling may help him/her reach these goals? (Is there “buy-in” to schooling)	What do you want to be when you grow up? How does your school help you with that?*
12	Student perception of science instruction	What does the student think about his/her science class? How does the student perceive science instruction	Do you like your science class? Tell me about what you’re doing in your science class right now.
13	Student perception of differences between science learning and their life-world	Does the student bridge between everyday life and school science learning? Where are the differences between everyday life and school science learning?	How do you think what you learn in science class relates to your everyday life? How do you see science different from what you learn at home?
14	Student perception of Fossil Finders project	How does the student perceive the Fossil Finders project?	What is the Fossil Finders project all about?



15	Student perception of differences between science learning and their life-world	Does the student bridge between everyday life and school science learning through inquiry? Where are the differences between everyday life and school science learning through inquiry?	What do you feel are the similarities and differences between what you learn during Fossil Finders and what you learn during your regular science classes/ learn at home?
16	Students' views on NOS	What are the student's understandings about NOS?	Do all scientists do science the same way? Do all scientists agree?
17	Students' views on NOS	What are the student's understandings about science and it's positionality with other ways of knowing?	Do all people agree with scientists?
18	Self-identification with science	Does the student consider himself/herself connected to science and science learning?	Would you describe yourself as a scientist? Why/why not?
19	Understandings about inquiry	How does the student approach a new situation? Is there science involved?	What do you do to learn about something that you're curious about?
20	School learning environments (Instructional congruency)	Does the student receive structured support to learn new science terms?	What do you do to learn new words used in science?
21			Is there anything else you'd like to add?

\*Questions drawn from Sofia Villenas' Spring 2008 Seminar Group (on Identity and Funds of Knowledge)

## **APPENDIX I**

### **Student Follow-Up Interview Script**

*Focus students were asked these questions following a scientist's visit to the classroom:*

1. What do you think about fossils?
2. If you like fossils, what made you interested in fossils?
3. What was it like meeting a scientist?
4. Does meeting a scientist it change what you think about science? How?
5. What did you learn about what scientists do?

## APPENDIX J

### Parent Interview Script

Purpose: Setting the stage for understanding students, how schooling is perceived by families, and perspectives on science. Consider subtle ways of getting at some to this information through a narrative approach (eliciting stories, life examples, etc.)

	<i>What I'm trying to get at</i>	<i>Academic Question</i>	<i>Rephrased Question</i>
1	Background: Name	What is the parent's name?	What is your name?
2	Background: Self-perception	How does the parent perceive him/herself?	How would you describe yourself?
3	Background: Place of origin	What is the family's place of origin?	Where is your family from?
4	Background: Languages spoken	What is the parent's linguistic background?	Do you speak another language? What language?
5	Background: Setting	What is the parent's line of work? What sorts of home tasks are taken up in the home?	Tell me about a typical day of work in and out of your home*
6	Background: Sense of place and values	What is the setting in which the student lives? What are the values of this community?	Tell me about your neighbors and your community. Who do you admire in your community and why?*
7	What the student does outside of school	What does the student do after school?	Tell me about your child's typical after-school activities*
8	Parental mentorship (Rogoff's apprenticeship; Community of Practice)	What activities does the student participate in together with the parent?	What activities do you and your child do together?*
9	Framing perspectives on education: learning outside of school	What kinds of attributes and what kind of learning does the parent value? How is this manifested?	What do you think are the most important lessons your child is taking away from you and his/her home life? How about from your neighbors and community life?*
10	Framing perspectives on education: learning outside of school	What kind of knowledge does the parent value?	What do you think is important to teach your child? What do you know best that you would like to pass on?*
11	Framing perspectives on education: school, schooling, and learning outside of school	What kind of learning experiences does the parent provide? How does the parent view school learning?	What are your children gaining from home that they do not get at school?*
12	Framing perspectives on education: school, schooling, and learning outside of school	What kind of learning experiences does the parent provide? How does the parent view school learning?	How different is the education your child receives at school from what your child learns at home?*
13	Framing perspectives on education: school and schooling	How does the parent view school learning?	What do you think of the education your child is receiving?*

14	Framing understandings about science	How does the parent view science? How does the parent frame science for the student?	From your perspective, what is science all about?
15	Framing understandings about science: NOS	How do parents conceptualize NOS?	How do you think scientists solve problems?
16	Framing understandings about science and culture	How do parents enact problem-solving activities that may be scientific in their everyday lives?	Can you tell me about a problem you've had to solve and what you did to figure it out?
17	Framing understandings about science: NOS	How do parents understand the creative components of science? Do they view science as being objective and truth?	Do all scientists do science the same way? Do all people agree with scientists?
18	Framing understandings about science and culture	How do parents understand the culturally based components of science?	Does science provide all of the answers to our questions? Y/N- Elaborate. Tell me about an example of other ways of understanding the world around us.
19	Framing understandings about science: NOS and culture	How can people influence science? Is it possible to change science?	Do you think science can change based on who is involved with it? Why/why not? Does new information change science?
20	Rogoff's apprenticeship; Community of Practice	What has the parent learned from the child about the project?	What have you learned about the Fossil Finders project through your child?
21	Rogoff's apprenticeship; Community of Practice; Enculturation?	What does the parent think about involving students in the activities, context, and culture of science?	Do you think that participating in research is a good way to learn about science?
22	Funds of knowledge; Cultural understandings	What does the parent consider needed to be included in science teaching in schools?	What else should schools teach about science/understanding the world?
23			Is there anything else you'd like to add?

\*Questions drawn from Sofia Villenas' Spring 2008 Seminar Group (on Identity and Funds of Knowledge)

## **APPENDIX K: ADDITIONAL INTERVIEW FINDINGS**

### *Cultural Learning at Home Went Mostly Unrecognized by Parents.*

Interviews with focus students' parents indicated that most of them did not fully recognize the cultural learning within the context of their own homes. Though I asked these questions to validate home cultures and ways of knowing (see Appendix J), it seems that parents themselves largely did not view the extent to which their homes were also learning environments. The following examples drawn from interviews with parents support these claims.

I conducted an interview with Alyssa's mother in Spanish in the context of her own home. Alyssa's mother was a recent immigrant from Puerto Rico and worked as a house keeper in other peoples' homes. The home was well maintained and photographs of Alyssa, or "nuestra princesa" (translation: our princess) outlined the living room walls. Alyssa's mother also had another small boy who was about 2 years old. While conducting the interview, the entire family, which included Alyssa's mother, her husband, Alyssa, and the little brother, sat in the living room. When I asked questions about what Alyssa learned at home, Alyssa's mother mostly referenced learning respect and learning how to clean her room. I probed her about other types of cultural knowledge; however, Alyssa's mother did not mention the fact that Alyssa also learned Spanish in the context of the home and how to cook ethnic dishes. Alyssa, however, in an interview talked about how she learned how to make a Puerto Rican dish over the phone with her grandmother. It may be inferred that she valued the family recipe and needed to have utilized her Spanish language skills in order to obtain the recipe from her grandmother.

I interviewed Paula's mother at her work site, where she was a caretaker for an elderly woman. This interview was also mostly conducted in Spanish. Paula's mother talked about her experiences in the United States and her views on the importance of a

strong family. Other than Paula, she has two other children. Paula's mother indicated that home learning included cooking together with her daughter, playing video games, and working on home projects. Though she stated that she wanted to pass on cultural customs to her children, "not like the Americans," she did not include language as a component of culture. In an interview with Paula, however, she indicated that her Spanish language skills were not that strong. Nonetheless, Paula was enrolled in a bilingual classroom by her parents, presumably.

In an interview with Bianca's mother over the phone, I learned that Bianca's parents had different backgrounds. While Bianca's mother identified herself as Caucasian, she explained that Bianca's father was from Puerto Rico. They had enrolled Bianca into a bilingual classroom, in what Bianca's mother said was a great school, so that she can learn to have an open mind and to accept more than one culture. Bianca's mother also indicated interest in helping Bianca keep traditions. Nonetheless, she did not elaborate on what this meant. Like the most of the other parents described above, Bianca's mother did not mention learning Spanish at home as a part of home learning.

I spoke with both of Raul's parents over the phone. Though I was initially interviewing Raul's mother, his father also wanted to share his views, thoughts, and perspectives about school and schooling, which I share below. Raul's mother described herself as Hispanic. Her family had moved to New York State from Puerto Rico and she dedicated herself to being a stay at home mom. "I don't work, I stay home," she stated. She also shared that she encouraged her son to Spanish since kindergarten and that they spend a lot of time together. Activities they do together include going to the movies, cooking, and house projects. However, important lessons Raul's mother feels he learns at home include caring, having an open mind, and paying attention. She also feels that home learning, interacting with people, and the

opportunity to be one on one is important to his development. Again, Raul's mother did not acknowledge the possible cultural components of some of the learning that occurs at home, such as views shaped by experiences, traditional recipes, and even the type of Spanish that Raul was learning at home.

Together, most of these parents shared views of home learning shaping character and including discipline. While many parents indicated valuing culture and tradition, they did not include this as an integral part of the home learning environment. For example, Alyssa's, Paula's, and Bianca's mothers made no mention of language learning at home. While some of the mothers made reference to teaching their children how to cook, they did not tie this to any form of cultural learning either. Though these parents presumably all maintained high esteem for cultural values by having enrolled their children into a bilingual classroom, it is fair to conclude that home learning of language and culture remained largely unrecognized based on interview responses.

## **APPENDIX L**

### **Fossil Finders Curriculum**



# Tricky Tracks:

## A background lesson to the Fossil Finders Investigation

*Fossil Finders Pilot Curriculum, Cornell University—Summer 2008*



### Lesson Description

This lesson engages students in the nature of science. Students will learn about making observations and inferences based on evidence. In this lesson, students will be introduced to the work of paleontologists and engage in interpreting the geologic past.

### Lesson Synopsis

The activity encourages students to observe and make inferences about evidence related to a partially complete set of animal tracks. Students will use their observations to interpret what they see. Student may be paired to make predictions, compare results, and discuss their findings.

**Time Estimate:** 50 minute class period

### Lesson Goals: Students will...

- Distinguish between observations and inferences
- Propose explanations and make predictions based on evidence
- Recognize and analyze alternative explanations and predictions
- Recognize that scientific explanations are subject to change as new evidence becomes available
- Recognize that scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and yield accurate predictions, when appropriate, about

systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public. Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific hypotheses or theories.

### National Science Education Standards Grades 5-8 (ages 10 - 14)

As a result of activities, students should develop an understanding of:

#### CONTENT STANDARD D: Earth and Space Science

- Earth's History

#### CONTENT STANDARD G: History & Nature of Science

- Science as a human endeavor
- Nature of science

### Materials

- Overhead projector
- Tricky Tracks Overhead Slide or PowerPoint
- Piece of paper

### Preparation:

Make an overhead transparency of the [footprint puzzle](#) from the master provided on page 89 or use the PowerPoint from the Fossil Finders website. Have a blank piece of paper on

hand to mask the puzzle when it is put on the projector.

#### Teacher Resources

- This activity is available at:  
<http://www.nap.edu/html/evolution98/evol6-e.html>
- Student Resource Sheets (attached)
- KWL Vocabulary

### INVESTIGATION

#### Engage:

Project **position 1** of the footprints from the overhead while covering the other two positions with a blank piece of paper or use the TrickyTracks PowerPoint presentation. Ask students to write down as many observations as they can about **position 1**.

*Next, have students partner with another student to discuss their observations. Allow a few minutes for students to confer with their partner.*

*Bring the class together and ask groups to share their observations.*

*Possible student responses may include: These are animal tracks, one set of tracks is larger and one set is smaller, one is red, one is green, they are heading towards the same point, etc....*

After students have given their responses talk to them about the statements that are observations and the statements that are inferences. Discuss the differences between the two kinds of statements.

**Observation:** Observations can be made with only the five senses.

Ex. one is red or one is green

**Inference:** Inferences involve a decision being made about something you observe.

Ex. These are animal tracks, one set of tracks is larger and one set of tracks is smaller, or they are heading towards the same point. Inferences here include calling the marks "animal tracks" or stating they are moving towards the same point. One can only label these as animal tracks if they observed the tracks being formed.

Tell the students that these are in fact dinosaur tracks. Fossilized footprints like these are common in parts of New England and in the southwestern United States. Point out to the students that they will be attempting to reconstruct happenings from the geological past by analyzing a set of fossilized tracks. Their problem is similar to that of a detective. They are to form defensible explanations of past events from limited evidence. As more evidence becomes available, their hypotheses must be modified or abandoned. The only clues are the footprints themselves.

Ask the students: Can you tell anything about the size or nature of the organisms? Were all the tracks made at the same time? How many animals were involved? Can you reconstruct a series of events represented by this set of fossil tracks?

Have the students discuss each of the questions. Accept any reasonable explanations students offer. Try consistently to point out the difference between what they observe and what they infer. Ask them to suggest evidence that would support their proposed explanations.

### Explore:

Reveal the second position of the puzzle and allow time for the students to consider the new information. Use the think, pair, share strategy from earlier. Students will see that the first explanation may need to be modified and new explanations may need to be added.

Next project the complete puzzle and ask students to interpret what happened. A key point for students to recognize is that any reasonable explanation must be based only on those proposed explanations that still apply when the entire puzzle is projected. Any interpretation that is consistent with all the evidence is acceptable.

Should it become necessary to challenge the students' thinking and stimulate the discussion, the *following questions may help*. In what directions did the animals move? Did they change their speed and direction? What might have changed the footprint pattern? Was the land level or irregular? Was the soil moist or dry on the day these tracks were made? In what kind of rock were the prints made? Were the sediments coarse or fine where the tracks were made? What environment could you find tracks like these today?

Students should give evidence or suggest what they would look for as evidence to support their proposed explanations.

The environment of the track area also should be discussed. If dinosaurs made the tracks, the climate probably was warm and humid. If students propose that some sort of obstruction prevented the animals from seeing each other, this might suggest vegetation. Or perhaps the widened pace might suggest a slope. Speculate

on the condition of the surface at the time the footprints were made. What conditions were necessary for their preservation?

### Explain:

An imaginative student should be able to propose several possible explanations. One of the most common is that two animals met and fought. No real reason exists to assume that one animal attacked and ate the other. Ask students who propose this explanation to indicate the evidence. If they could visit the site, what evidence would they look for that would support their explanation? Certain lines of evidence—the quickened gaits, circular pattern, and disappearance of one set of tracks—could support the fight explanation. They might, however, support an explanation of a mother picking up her baby. The description and temperament of the animals involved are open to question. Indeed, we lack the evidence to say that the tracks were made at the same time. The intermingling shown in the middle section of the puzzle may be evidence that both tracks were made at one time, but it could be only a coincidence. Perhaps one animal passed by and left, and then the other arrived.

Discuss the expected learning outcomes related to scientific inquiry and the nature of science. To answer the questions posed by the set of fossil footprints, the students, like scientists, constructed reasonable explanations based solely on their logical interpretation of the available evidence. They recognized and analyzed alternative explanations by weighing the evidence and examining the logic to decide which explanations seemed most reasonable. Although there may have been several plausible explanations, they did not all have equal weight. In a manner similar to the way scientists work,

students should be able to use scientific criteria to find, communicate, and defend the preferred explanation.

### Elaborate/Extend:

Classes can have more discussions on interpreting series of events using animal prints students find outdoors and reproduce for the class. Do not forget to look for human footprints. Have students design a different fossil footprint puzzle. Choose several different ones and have student teams repeat the activity using the same learning goals.

### Concluding Discussion:

[Add conclusions]

### Evaluate:

Describe a specific event involving two or more people or animals where footprint evidence remains. Ask the students, either in teams or individually, to diagram footprint evidence that could lead to several different, yet defensible, explanations regarding what took place. Have the students or teams exchange footprint diagrams and see if they can determine explanations for these footprints. They should be able to explain the strengths and weaknesses of each explanation using their footprint puzzle.

Teachers may also choose to evaluate their students based on participation in the activity or by collecting their observations and drawings they complete during the activity.

### Homework:

[Add here]

### Before the Next Session:

[Add here]

### Teachers Tips:

[Teacher-generated tips for implementing this lesson plan...]

### ELL Adaptations:

#### 1) Include a variety of cultural experiences and materials in instruction.

- How do other cultures understand the geologic past? Ask students.
- What are some examples of observations/inferences made by people from other cultures? (i.e. is the world round?)

#### 2) Share scientific authority

- Respond to student questions with further probing questions.
- Employ the use of a student journal to record their observations and explanations
- Invite students to try Tricky Tracks at home with family (provide hand-out on paper). What do family members think?

#### 3) Encourage the use of students' home language to enhance understanding in classroom instruction.

- Supplement KWL charts and graphic organizers with use of native language and student sketches
- Invite the use of native language for classroom discussion, reading, note-taking
- Group students to communicate in native language when using reciprocal teaching and other instructional strategies

#### 4) Tailor verbal communication (in English) to enhance students' understanding

- Provide visual aides when introducing students to new vocabulary and concepts.
- Use hand and facial gestures

#### Resources Included:

- K-W-L Vocabulary List

#### References:

- Barton, M. L., & Jordan, D. L. (2001). Teaching reading in science: A supplement to the Second Edition of Teaching Reading in the Content Areas Teacher's Manual. Aurora, CO: Mid-continent Research for Education and Learning.
- Luykx, A., & Lee, O. (2007). Measuring instructional congruence in elementary science classrooms: Pedagogical and methodological components of a theoretical framework. *Journal of Research in Science Teaching*, 44(3), 424-447.

## TEACHER RESOURCES

### References

[Maintain an updated of the references such as books, materials and sources used in developing the lesson to include here]

- Bibliography
- Annotated related web sites with url/ addresses
- Related organizations
- Overheads or power point presentation

### Internet Connections

- McREL Compendium of Standards and Benchmarks ([www.mcrel.org/standards-benchmarks](http://www.mcrel.org/standards-benchmarks)) A compilation of content standards for K-12 curriculum in both searchable and browsable formats.
- National Science Education Standards ([www.nsta.org/standards](http://www.nsta.org/standards))
- Ichnowiki - website about trace fossils ([http://www.campusdakota.com/wiki/index.php?title=Main\\_Page](http://www.campusdakota.com/wiki/index.php?title=Main_Page))
- Dinosaur Tracking (<http://drscavanaugh.org/dino>)

### Recommended Reading

- National Academy of Sciences (1998). *Teaching about evolution and the nature of science*. Washington, D.C.: National Academy Press. (ISBN: 0309063647)
- Pojeta, J. & Springer, D. (2001). *Evolution and the fossil record*. Alexandria: American Geological Institute. (ISBN: 0922152578)

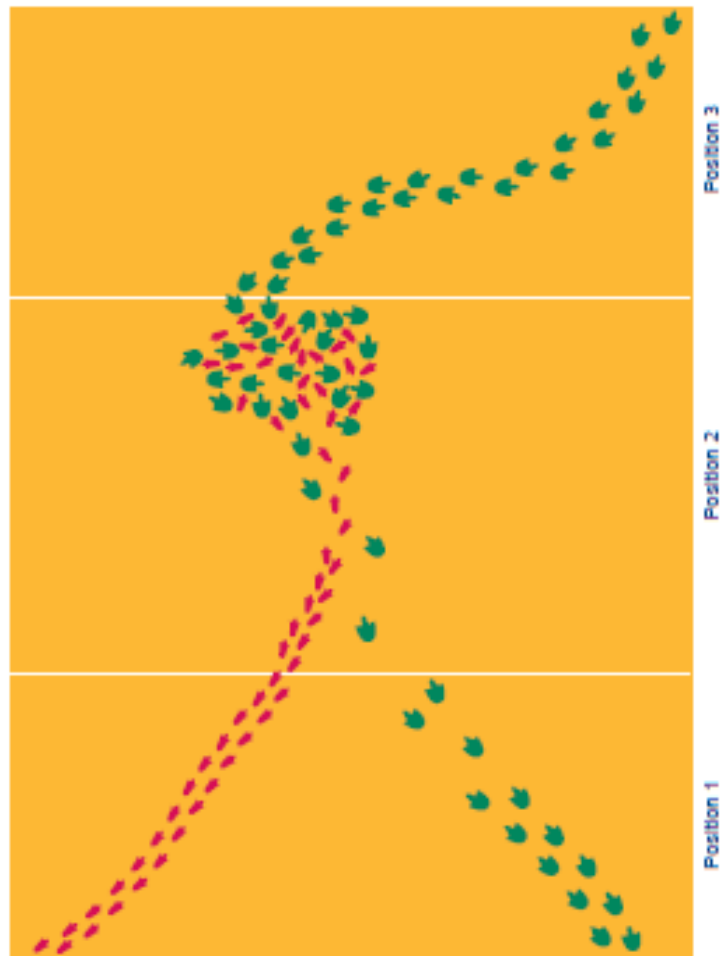
**\*[ADD HERE AS WE GO ALONG]**

## STUDENT RESOURCES

Student resources are included below in the form of vocabulary development support.

- The K-W-L chart included below supports students in activating prior knowledge, establishing relevancy, and encouraging reflection. Adaptations for ELL may include using student's home languages and drawings.

DRAFT



# Measuring Fossils

## A background lesson to the Fossil Finders Investigation

*Fossil Finders Pilot Curriculum, Cornell University—Summer 2008*



### Lesson Description

This lesson engages students in an exploration of fossils from the Devonian period. As a background component of the Fossil Finders investigation, students will learn how to identify and measure fossils and process the data that they gather. Students will learn how this work relates to the work of scientists.

### Lesson Synopsis

The activity parallels the work of scientists and engages students in identifying fossils, and gathering their measurement data. Students will use data recording sheets to gather data related to the fossil samples.

**Time Estimate:** 50 minute class period

### Lesson Goals: Students will...

- Count fossils
- Identify the organisms in the rocks
- Measure the organisms.
- Discuss and practice filling in data sheets.

### National Science Education Standards

*Grades 5-8 (ages 10 - 14)*

As a result of activities, students should develop an understanding of:

#### CONTENT STANDARD D: Earth and Space Science

- Earth's History

#### CONTENT STANDARD G: History & Nature of Science

- Science as a human endeavor
- Nature of science

### Materials:

- Ruler with metric
- Hand lens
- Fossil ID Sheet (class set)
- Data Recording Sheets (class set)

### Preparation:

Print fossil ID and Data Recording Sheets.

### Resources

Teacher Resource (attached)

- Geological Time Scale
- References

Student Resource Sheets (attached)

- Frayer Model Concept Map

### INVESTIGATION

Explain the Fossil Finders study: Rocks were collected from a cliff in Central New York located near Ithaca. They are about 400,000,000 years old (Show geologic time scale again so kids will see how old these rocks/fossils are).

You will be the first group to study the organisms living in these rocks. Similarly to how scientists work, it's not certain what you will find, though you can have some ideas about what is possible. Scientists build from each other's work. Because of the prior work of scientists, we have some ideas about what other researchers have found that can help us





in our work. Here are some of the common animals that were alive during the Devonian Period in New York (Pass out ID sheet).

Today we will learn how to do four things that will help us become involved in the work of scientists: A) Count fossils B) Identify the organisms in the rocks C) Measure the organisms. D) Learn how to fill in data sheets.

*Strategies for counting fossils.*

- What should you do if there are no fossils on the rock? What do you do if there are an overwhelming number of fossils in the rock?
  - Go through basic ID's and talk a little about each organism. Have students identify fossils in rocks. Help with strategies for counting fossils. Bring group together and discuss problems and issues with ID's. What confusion exists, questions, etc...?
  - Go over measurements. Have students practice measuring fossils. Bring group together and discuss problems and issues with measurements. What confusion exists, questions, etc...?
  - Put together a PowerPoint and overheads with measurement examples. This may include colored photos of rocks with many fossils. Strategies for measuring, identifying, etc. can be discussed here.
  - Consider using some type of transparent card to help kids measure and section off parts of the rock for counting or another way to estimate the number of organisms on a rock....
- Pass out data sheets and talk with students about how they will fill out data. Have a sample data sheet filled out to show student how it is done.

# Investigating Fossils:

## A background lesson to the Fossil Finders Investigation

*Fossil Finders Pilot Curriculum, Cornell University—Summer 2008*



### Lesson Description

This lesson engages students in an exploration of fossils. As a background component of the Fossil Finders investigation, students will learn about what fossils are and how they formed. In this lesson, students will be introduced to the work of paleontologists and engage in making inferences about the geologic past using fossils.

### Lesson Synopsis

The activity encourages students to work in pairs to observe, draw, and make inferences about fossils. Students will make observations and use their knowledge of the environment and modern day processes to make inferences about the environments in which fossilized organisms once lived. Student pairs make predictions, compare results, and discuss their findings.

**Time Estimate:** 50 minute class period

### Lesson Goals: Students will...

- Distinguish between observations and inferences
- Define the term fossil and paleontologist
- Describe the concept of uniformitarianism
- Discuss how a paleontologist might study the past
- Apply what a paleontologist does to study a particular rock
- Recognize that fossils are evidence of the past

### National Science Education Standards

*Grades 5-8 (ages 10 - 14)*

As a result of activities, students should develop an understanding of:

#### CONTENT STANDARD A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

#### CONTENT STANDARD D: Earth and Space Science

- Earth's History

#### CONTENT STANDARD G: History & Nature of Science

- Science as a human endeavor
- Nature of science

### Materials

- rock with fossils
- Investigating Fossils Work Sheet or scratch paper
- pencil

### Preparation:

Group students into teams of 2 - 4.

Provide a rock sample with fossils, paper, and pencil to each student or group of students participating in the activity.

### Resources

Teacher Resource Documents (attached)

- Geologic Timeline
- Fossil Drawings
- Article: Fossils and Environmental Change
- References

Student Resource Sheets (attached)

- KWL Vocabulary
- Frayer Model



- Discussion Map

### Introduction:

Teacher invites the class to be part of a real scientific investigation.

**Say:** Scientists in Ithaca, New York working at the Paleontological Research Institution and its Museum of the Earth have asked for our help. We have been asked to help scientists investigate the question: How does sea life respond to changes in the environment? To do this we will study what kinds of animals were living millions of years ago in the Finger Lakes Region of New York. Along with scientists and other students we will try to learn how (and if) sea life changed, and if these changes relate to environmental changes. This data might help scientists understand climate change today. Scientists from all over the US and even the world can use our data.

**Ask:** Why do you think it is important to learn about what the earth was like a long time ago? Why might we be interested to see how organisms reacted to changes in the environment?

Teachers who have traveled to Ithaca for the summer workshop may want to talk about their summer work. For instance: This summer I spent a week in the Finger Lakes area, working with the Museum of the Earth. Teachers should discuss where Ithaca, NY is and how Ithaca looks compared to where they live. A PowerPoint with a map locating Ithaca and pictures of waterfalls and gorges is available. Teachers who did not attend the professional development should give a basic explanation of what paleontologists do.

This is also a good time to explain that there are not enough paleontologists to study all the

fossils and rocks and because of this, paleontologists need help from students. For example, if 40 students work for one-hour each studying fossils in rocks, it is like one paleontologist working for an entire week! Teachers may also want to show some digital photos that they took with their new cameras at the summer workshop.

**Say:** We will be the first ones to collect these data. Nobody else has looked at these samples and knows what will be found! We will use these data to learn about science, share with scientists and other classes, and perhaps answer some questions of our own or other classes.

## INVESTIGATION

### Engage:

[\*Note: Some teachers may prefer to begin with this part of the activity and discuss the introduction material later.]

Pass out a rock sample to each group of students and an Investigating Fossils Work Sheet or scratch paper to each student.

**Emphasize that scientists work in teams (NOS).**

Ask students to draw what they see in the rock or write down observations about the rock. Allow time for each group of students to describe briefly what they see in their samples.

*Possible student responses may include:* The rock is dark in color, hard, jagged, etc. There are shells or fossils inside the rock. Introduce the term **fossil**, preserved remains or traces of animals, plants, and other organisms from the past. Students may also include inferences. Be sure to re-address the difference between



inferences and observations. Teachers of younger grades may want to focus on what fossils are and what fossils look like. What makes something a fossil? How do fossils look? Do all fossils look same? How can you tell if something is a fossil or just an interesting shape or color on the rock? Have students look at rocks that have fossils and others that do not. [Note: This could potentially be a class period in and of itself]

### Explore:

Ask students to draw a picture of what they think one of their fossils might have looked like when it was alive (here you are asking them to make an interpretation/inference). Tell them to include its environment or surroundings.

### Explain:

What is the basis for your interpretation? Have students share their drawings and explain why they drew them the way they did.

*Possible questions include:* Where could these organisms have lived? How do you know this? Why did you put your shell in water? Why did you put legs on that organism? Where might you have seen things like this before?

Point out to students that in historical sciences much of what we know comes from modern organisms. Also, scientists make inferences. Since modern shells are normally found in and around water we might infer that ancient shells were also found in water (the present is key to the past, **uniformitarianism**).

Just as students used their knowledge to think about what the fossils were like during life, scientists like **paleontologists** (scientists who study ancient life by looking at fossils) use the present to study the past because they cannot go back in time to learn about how things were.

### Elaborate/Extend:

Ask students what questions they have about the fossils and rocks they were looking at.

*Possible questions include:*

- 1) How old are the fossils?
- 2) How did the fossils get in the rocks?
- 3) What are paleontologists doing?

*If these questions are not brought up, ask students these questions to open up conversation.*

### A Long Time Ago!

1) To help students understand the age of the rock/fossils, set-up a geologic timeline in front of the classroom. Pace or measure off 4.6 meters (*If the chalkboard or whiteboard is long enough it may be helpful to make a timeline there*).

The beginning of the timeline represents Earth when it first formed, the end of the line represents present day. Call students up to stand on the timeline to represent organisms that existed in the past. Several websites that have timelines include:

- 1) <http://math.ucr.edu/home/baez/timeline.html>
- 2) [http://www.talkorigins.org/origins/geo\\_timeline.html](http://www.talkorigins.org/origins/geo_timeline.html).

Choose several well known organisms or events in Earth's history to help give students a context for when the organisms in these rocks were living.

- Rise of single celled organisms = 3-billion years ago (pace ~1.6 meters or 1.6 steps from Earth's formation and have a student stand there).
- Multi-celled organisms = 1-billion years ago (pace ~3.6 meters or 3.6 steps from

Earth's formation and have a student stand there).

- Rise of the dinosaurs = 205 million years ago (20.5 cm from present day)
- Extinction of dinosaurs = 65-million years ago (place a student ~ 6.5 cm from present day).
- Rise of modern humans = 50,000 years ago (last mm of the timeline).
- Pleistocene extinction of large Ice Age mammals = 10,000 years ago (last mm of the timeline)
- The fossils in these rocks existed around 400 million years ago or ~ 40 cm from present day.

\*We suggest taking a digital photo of your students in the timeline and to hang this in the school hallway.

#### *Fossils Get Preserved:*

To get students thinking about how fossils got preserved in the rocks, ask for their ideas. A good way to help them conceptualize is to pour sand, dirt, or cement over a modern shell and discuss what happens to a shell as more sediment piles (compaction) on and water seeps through (cementation). You can explain how water and other fluids seeping thorough act as glue and the sediment that piles on pushes the material together which forms rock.

#### *Fossils and Climate Change*

To provide students with resources for understanding the relevancy of paleontologist's work in relation to climate change, current media can be reviewed. The following article describes recent findings:

<http://www.livescience.com/environment/080722-antarctic-warmer.html>

Students can read and discuss the following question in small groups: How do fossils give us information about the geologic past?

#### *Fossils and Evolution:*

To provide students with resources for understanding the relevancy of paleontologist's work in relation to understanding changes in populations, current media can be reviewed. The following article describes recent findings:

[http://www.nsf.gov/news/news\\_summ.jsp?cntn\\_id=11785&govDel=USNSF\\_51](http://www.nsf.gov/news/news_summ.jsp?cntn_id=11785&govDel=USNSF_51)

Students can read and discuss the following question in small groups: How do fossils give us information about the geologic past?

#### *Concluding Discussion:*

[Add conclusions]

#### *Evaluate:*

The Fossil Finders curriculum encourages ongoing evaluation of student learning that is embedded into instruction. Several tools are also suggested to evaluate student learning. These include the following rubrics:  
[ADD RUBRICS]

#### *Alternative Activities:*

Draw a T. rex

<http://www.uky.edu/KGS/education/trex.html>

Coffee Ground Fossils

<http://crafts.kaboose.com/fossil.html>



Sorting Activity  
[www.education.com/activity/article/Nuts\\_Bolts\\_Kindergarten/](http://www.education.com/activity/article/Nuts_Bolts_Kindergarten/)  
**Homework:**  
[Add here]

**Before the Next Session:**  
[Add here]

**Teachers Tips:**  
[Teacher-generated tips for implementing this lesson plan...]

**ELL Adaptations:**

**1) Include a variety of cultural experiences and materials in instruction.**

- Where else in the world can fossils be found? Ask students to provide examples.
- How do other cultures understand the geologic past? Ask students how other cultures may interpret the past.
- Provide reading materials in students' native languages.

**2) Share scientific authority**

- Respond to student questions with further probing questions.
- Employ the use of a student journal
  - *Journal can follow the Bybee 5E format and include reflection questions that engage students and encourages them to explore, elaborate, explain, and evaluate.*
- *Include space for parent involvement by engaging students in interviewing their families and assigning collaborative projects.*

**3) Encourage the use of students' home language to enhance understanding in classroom instruction**

- Supplement KWL charts and graphic organizers with use of native language and student sketches
- Invite the use of native language for classroom discussion, reading, note-taking
- Group students to communicate in native language when using reciprocal teaching and other instructional strategies

**4) Tailor verbal communication (in English) to enhance students' understanding**

- Provide visual aides when introducing students to new vocabulary and concepts.  
*For example, use a drawing that would depict "sedimentation."*  
[See Teacher Resources for examples]
- Encourage students to supplement note taking with drawings, or "cartoon notes" during direct instruction
- Use hand and facial gestures

**Resources Included:**

- Fossil Sample Photos
- Investigating Fossils worksheet
- K-W-L Vocabulary List
- Frayer Model
- Discussion Map

#### References:

- Barton, M. L., & Jordan, D. L. (2001). Teaching reading in science: A supplement to the Second Edition of Teaching Reading in the Content Areas Teacher's Manual. Aurora, CO: Mid-continent Research for Education and Learning.
- Luykx, A., & Lee, O. (2007). Measuring instructional congruence in elementary science classrooms: Pedagogical and methodological components of a theoretical framework. Journal of Research in Science Teaching, 44(3), 424-447.

#### TEACHER RESOURCES

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- Bibliography
- Annotated related web sites with url/addresses
- Related organizations
- Overheads or power point presentation

##### Internet Connections

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- National Science Education Standards ([www.nsta.org/standards](http://www.nsta.org/standards))

- Understanding Geologic Time (<http://www.ucmp.berkeley.edu/education/explorations/tours/geotime/>)
- The Paleontology Portal (<http://www.paleoportal.org/>)

##### Recommended Reading

- National Academy of Sciences (1998). *Teaching about evolution and the nature of science*. Washington, D.C.: National Academy Press. (ISBN: 0309063647)
- Pojeta, J. & Springer, D. (2001). *Evolution and the fossil record*. Alexandria: American Geological Institute. (ISBN: 0922152578)

**\*[ADD HERE AS WE GO ALONG]**

#### STUDENT RESOURCES

Student resources are included below in the form of vocabulary development support.

- The K-W-L chart included below supports students in activating prior knowledge, establishing relevancy, and encouraging reflection. Adaptations for ELL may include using student's home languages and drawings.
- The Frayer Model included below aims to provide structured support to students in developing conceptual understandings. It draws on student knowledge of terms and tying classroom learning to student home experiences and knowledge. In this way, students are encouraged to bring cultural knowledge into the classroom.



- The Discussion Model encourages students to use evidence in developing an argument or position. This model is useful for structuring responses to questions related to article readings or reflective assessments of classroom learning.

DRAFT



# Fossil Finders Investigation:



*Fossil Finders Pilot Curriculum, Cornell University—Summer 2008*

## Lesson Description

This five-day investigation engages students in scientific inquiry and the nature of science. Students will learn about collecting and compiling data related to a population of fossils. Students will then analyze and interpret the data they collected and enter the data in an on-line database for future use by students and scientists.

## Lesson Synopsis

The activity encourages students to engage in the work of paleontologists by collecting measurements of fossil samples. Students will use concepts of mean, median, and mode to process this data. Data will then be entered into a database, charted and graphed. Students will use the data to make interpretations about the past. Student may be paired to make predictions, compare results, and discuss their findings.

## Time Estimate:

**5 days- 50 minute class periods**

## Lesson Goals: Students will...

- Identify several Devonian fossils using an identification chart.
- Measure fossils using metric measurements.
- Record data on a data sheet or web data base.
- Verbalize challenges encountered during the investigation.
- Use basic statistics to summarize their results.

- Read aggregated data and make inferences and hypotheses based on this data.
- Participate in an authentic scientific investigation.
- State that scientists develop explanations of the world by using observations.
- Describe the work of scientists, that they use their senses to make observations; and to compare and contrast an observation and an inference.
- Describe the creative aspects of science

## National Science Education Standards Grades 5-8 (ages 10 - 14)

As a result of activities, students should develop an understanding of:

### CONTENT STANDARD A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

### CONTENT STANDARD C: Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

### CONTENT STANDARD D: Earth and Space Science

- Earth's History

### CONTENT STANDARD G: History & Nature of Science

- Science as a human endeavor
- Nature of science

## Materials

- Fossil Samples in Zip lock Bags
- Masking Tape
- Rulers



- Hand lens
- Copies of Fossil Identification Sheet
- Copies of Initial Fossil Data Sheets for each fossil type
- Blank transparency sheets
- Overhead markers
- Measuring rubric
- Markers

### Preparation:

[Add here]

### Resources:

- Fossil Measurements PowerPoint
- Fossil Finders Website for Data Entry Teacher Resources (Attached)
- Information for Teachers
- Fossil Identification Sheet
- Initial Fossil Data Sheets for each fossil type (4 in all)
- Teacher measuring rubric

### Introduction:

Teacher invites the class to be part of a real scientific investigation.

[Note: Some teachers may have already done this depending on which background lessons they completed]

**Say:** Scientists in Ithaca, New York working at the Paleontological Research Institution have asked for our help. We have been asked to help scientists research the question: How does sea life respond to changes in the environment? To do this we will study what kinds of animals were living millions of years ago in the Finger Lakes Region of New York. Along with scientists and other students we will try to learn how (and if) sea life changed, and if these changes related to environmental changes. This data will help

scientists understand evolution and climate change today. Scientists from all over the US and even the world can use our data.

**Ask:** Why do you think it is important to learn about what the earth was like a long time ago? Why might we be interested to see how organisms reacted to changes in the environment?

Teachers who have traveled to Ithaca for the summer workshop may want to talk about their summer work. For instance: This summer I spent a week in the Finger Lakes area, working with the Museum of the Earth. Other teachers may discuss what paleontologists do. This is also a good time to explain that there are not enough paleontologists to study all the fossils and rocks and because of this, paleontologists need students help. For example, if 40 students work for one-hour each studying fossils in rocks, it is like one paleontologist working for an entire week! Teachers may also want to show some digital photos that they took with their new cameras at the summer workshop.

**Say:** We will be the first ones to collect this data. Nobody else has looked at these samples and knows what will be found! We will use this data to learn about science, share with scientists and other classes, and perhaps answer some questions of our own or questions posed by other classes.

## INVESTIGATION

### Engage:

**Ask:** Where can you go to find rocks? Where did these rocks come from? *Possible student*

*responses may include:* At the beach, dig a hole, at a quarry, road cut....

Ask students if they have ever seen a place with rocks exposed on Earth's surface. Show a picture of a gorge, road cut, etc. to help students. *Ask:* Why don't we find rocks everywhere on Earth's surface?

*Possible student responses may include:* They are covered by soil, houses, trees, etc.. This may be a good time to discuss erosion, weathering, and deposition.

Explain how often times rocks are in layers and paleontologists study these layers to learn about the past. Pose a question such as: Why might a paleontologist be interested in collecting rocks at many layers throughout a rock outcrop instead of just one layer? A picture similar to Figure 1 drawn on the board may help students give ideas for why a paleontologist would want to collect at various layers.

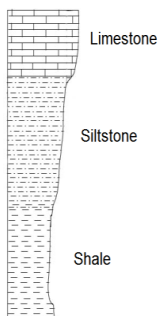


Figure 1 (background information for teachers): This is a stratigraphic column depicting a typical shallowing upward sequence (or sea level becoming shallower in a given place throughout time. This is common in the Middle Devonian. The locality in which these rocks were deposited was a shallow sea that experienced changing water depths. This column shows a time when the sea got progressively shallower evidenced by finer-grained shale (mudstone) at the bottom and coarser grained material like siltstone higher up. This pattern is similar to the localities from which Fossil Finders samples were collected.

*Possible student responses may include:* There may be different animals in different layers, or the rock might change from layer to layer, etc...

Discuss how/why a paleontologist chooses to sample. A possible question might be: Should a paleontologist only sample from places where there are lots of fossils? Should they sample a place where there are no fossils? You may choose to relate the idea of sampling to the classroom population study.

#### **Explanation of Activity:**

Pass out **Fossil Identification Sheet** and **Initial Data Sheets for each fossil type** and allow students time to study the fossils that may be present in the rocks. Teacher talks students through **initial data sheets**. First students need to recognize that there are four separate data collection sheets: 1) brachiopods, 2) bivalves, 3) horn coral, snails, crinoids, and 4) trilobites, cephalopods, and bryozoans. Walk students through all information to fill out at the top of each sheet such as class name, sample number, subsample number, and data collected by.

Explain how to fill out each sheet.

-For **brachiopods** and **bivalves** (sheets 1 and 2) students will measure in millimeters (mm's) in the A direction and B direction indicated on the handouts and PowerPoint slides. They will also indicate the color of the fossil and fragmentation.

-For all other organisms (sheets 3 & 4) the students need to first record what type of fossil they are measuring. Next they will measure length, width, color and fragmentation.

Each type of fossil has a special A and B measurement. Please reinforce with your students that it is very important to always measure the fossils in mm's and to be sure to accurately measure and record in the A

direction and the B direction. You may relate this to someone measuring the students own body (Would the person get an accurate measurement of height if they measured from ankles to neck instead of their entire body?)

Coloration is measured on a scale of 1-5 with 1 being the lightest shade of gray and 5 being black. Show your students examples of real rocks of certain colors so they can become familiar with the coloration scale in hand samples.

Fragmentation is the amount of the fossil that is preserved. It is measured on a scale of 1-5 with 1 being a whole fossil and 5 being a tiny piece of a fossil. The students can see the different amounts of fragmentation on the data collection sheets and PowerPoint displays.

[Note: You may choose to address common problems here (what to do with broken fossils, etc... see **Information for Teachers**) or wait until they arise.]

### Explore:

[Note: If you did not complete the "Exploring Fossils Activity or work with the ID fossils during the Background lessons please familiarize your students with fossil identification before beginning the exploration.]

Students work in teams to identify, measure, and record the fossils in their rocks. All groups will receive rock samples, a hand lens, transparency sheets, markers and light. Rocks will come in labeled Ziploc baggies (location, baggy #, no ID/measure).

Each student will choose a rock from the bag. Place a piece of transparency paper over the rock and trace the shape of the rock (for rocks with multiple fossils). Next, have the students trace each **brachiopod** on their rock with a **blue marker**. As they trace each fossil make sure that they mark the A and B direction. Once all brachiopods are traced, take the transparency off the rock and place it flat on the desk.

Measure each A and B direction for each fossil and record this on the data sheet. Also, record the color of the rock and fragmentation of each fossil on the data sheet. Once they have completed one type of fossil, move on repeating the process with a new transparency and **red marker** for **bivalves** and a new transparency and **green marker** for **all other types** of fossils.

After the students record the fossils in a particular rock they should place the rock into the pre-labeled baggie with the same label except no ID/measure does not appear on the baggie (location, baggy #). They will do this so they know which rocks they have measured and which still need to be measured.

Periodically throughout the Exploration, the teacher should bring students together to discuss problems that arise. See Information for Teachers for discussion ideas.

Once groups have identified and recorded the fossils in their rocks have each group record a summary of their data on the data summary sheet (Table 2). Students will include the name of each fossil group they identified, total number of that fossil, the median size A & B measurements (they will know this term from an earlier lesson), total number broken, and % broken. You may want to put a data table on

the board, overhead, or PowerPoint (Table 3) so the class can discuss overall findings.

[Note: If some groups finish early, they may help other groups identify and total their findings.]

Table 2. *Data summary sheet*

Fossil Type	Total Number	Median A Length	Median B Length	Mean Coloration	Mean Fragmentation
Ex. Clams	40	13	5	3	2

Table 3. *Overall class data*

Fossil Type	Total Number	Median A Length	Median B Length	Mean Coloration	Mean Fragmentation
Ex. Clams	Group 1 40	G1 13	G1 5	G1 3	G1 2
	Group 2 27	G2 11	G2 4.5	G2 1	G2 4
	Group 3 38	G3 17	G3 7	G3 3	G3 3

### Explain:

#### *Patterns:*

Have students look at class data and see what patterns exist.

*Ask:* What patterns do you see in the data?

*Possible student responses may include:* There is an abundance of one type of organism over others, some shells are more often broken than others, almost all shells are broken, certain species are larger than others, etc.

*Ask guiding questions including:*

Why do you suppose the class' numbers vary from sample to sample?

*Possible student responses may include:*

Identification error or other problems, some groups may only have a few of one type of fossil while others have a lot (sample size). This could lead to a good discussion on errors in the data.

Do you suppose there are errors in the data?

Is it okay to make errors?

*Ask:* Based on what you found in the rocks, what do you think central NY looked like during the Devonian Period (360 and 415 million of years ago)? What might it have been like if you visited central NY in the Devonian? Have students make drawings of what they believe the earth looked like during the Devonian. Compare drawings and discuss with the group what evidence they used to make the drawings. Will all drawings be the same? How much of historical science is interpretation?

*Ask:* How might someone "experiment" on something that is no longer alive like a fossil? Are we guessing or is there a way scientists can figure out what past environments were like? How could we figure out where shells get broken or what types of shells break more easily? See **Information for Teachers** to help with interpretation.

*Ask:* Do you think all scientists might interpret the data the same? What other interpretations can be made? Are there a lot of facts to support such interpretations? Can you make a plausible alternative hypothesis for what central NY once looked like based on the fossils you found?

*Graphing:* Have students make graphs of interesting data. Students could make histograms of a species population, or bar graphs using group data.

**After discussing data with students, the class should prepare its data for the scientists at the Paleontological Research Institution (send or input their data on the Website)**

### Elaborate/Extend:

#### *Conduct a Study:*

Discuss possible future studies and perhaps conduct a study based on student data.

*Ask:* What are some other things to study that can help us learn about these rocks?

*Possible student responses may include:* Amount of fossils per volume of rock, features like the size of eyes on trilobites, or percentage of a certain fossil across all groups that studied the rocks, how do related organisms live today, etc.

Conduct a biodiversity census of the school yard. Have your class document species abundance of plants or animals. Discuss which of these organisms would most likely be preserved in a "future fossil record" and why.

#### *Model Past Environments:*

Discuss how scientists and museums reconstruct what the earth might have looked like in the past. Have students make dioramas of what they think the environment, animals, and plants might have looked like.

Have students compare modern shells to ancient shells to discuss similarities and differences. This could open a discussion on evolutionary topics such as functional morphology, why evolution occurs, etc. [To be added]

*Graphing:* Have students graph information from other groups.

*Reports:* Have students design a report for web publication.

### Concluding Discussion:

[Add conclusions]

### Evaluate:

The Fossil Finders curriculum encourages ongoing evaluation of student learning that is embedded into instruction. Several tools are also suggested to evaluate student learning. These include the following rubrics:

[ADD RUBRICS]

### Homework: ?

[Add here]

### Before the Next Session:

[Add here]



### Teachers Tips:

[Teacher-generated tips for implementing this lesson plan...]

### ELL Adaptations:

#### 1) Include a variety of cultural experiences and materials in instruction.

- Discuss the differences of the use of centimeters and inches.

#### 2) Share scientific authority

- Respond to student questions with further probing questions.
- Employ the use of a student journal

#### 3) Encourage the use of students' home language to enhance understanding in classroom instruction.

- Supplement KWL charts and graphic organizers with use of native language and student sketches
- Invite the use of native language for classroom discussion, reading, note-taking
- Group students to communicate in native language when using reciprocal teaching and other instructional strategies

#### 4) Tailor verbal communication (in English) to enhance students' understanding.

- Provide visual aides when introducing students to new vocabulary and concepts.
- Use hand and facial gestures

### References:

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continent Research for Education and Learning.

- Luykx, A., & Lee, O. (2007). Measuring instructional congruence in elementary science classrooms: Pedagogical and methodological components of a theoretical framework. Journal of Research in Science Teaching, 44(3), 424-447.

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- National Science Education Standards ([www.nsta.org/standards](http://www.nsta.org/standards))
- The Paleontology Portal ([www.paleoportal.org](http://www.paleoportal.org))

#### Recommended Reading

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- Pojeta, J. & Springer, D. (2001). *Evolution and the fossil record*. Alexandria: American Geological Institute. (ISBN: 0922152578)

**\*[ADD HERE AS WE GO ALONG]  
INFORMATION FOR TEACHERS**

After a few minutes of exploration the teacher may chose to bring the students together to discuss challenges in identification. *Possible student responses may include:* Some rocks have a lot of fossils, others do not.

- Sometime it is difficult to tell if the fossil is broken or not. (*Teacher can discuss that sometimes things are not certain, scientists have to make their best guess. If the fossils are possibly broken, but it can be identified, identify it, but do not measure the fossil (this is why we are measuring fragmentation). This is a great place to discuss how science can be subjective!*)
- Some fossils are too small to identify. (*If this is the case, you might not be able to ID or measure it. Is this okay? What other things can be done? Consult an expert?*)
- Some fossils are broken; I can identify them, but it is hard to measure them. (*Identify the fossil, but do not measure it. Record the amount of fragmentation.*)
- Some fossils are partially hidden in the rock. Maybe there are more fossils in the middle. (*Do students think there could be more fossils in the rock? Should they break open the rocks? What would be some issues? Will this break the fossil? Are the other classes breaking open the rocks? What would happen if we did and they didn't?*)

Discuss that there are lots of complications in nature (scientists call this "noise"), but we can't just choose the best fossils and only measure these because it will not give us an accurate

depiction of what is really there. By trying our best to make accurate measurements we can cancel out a lot of the "noise". Examples of this could include: What if every group used metric (mm's) except one group that used standard (inches)? Could we tell that looking at the data?

***Interpretations:***

**Error in data:** Although we want to do are best to measure and identify accurately, with a large enough sample size occasional errors in identification and measurements are not too critical. If someone accidentally put down 200 mm instead of 20 mm for the size of a fossil we would see this outlier in the data. The best thing to do would be to go back and check that part of the data again. If we found out the fossil was 20 mm we could throw out the 200 mm measurement.

***Organism information:*** **Brachiopods** and **bryozoans** were filter feeders that did not move. Because they were filter feeders they did not do well in areas with lots of mud. If your sample has a lot of these it is safe to say the environment was not as muddy as an environment where clams would thrive.

In modern times, **clams** burrow in sandy or muddy sediments. Because this is where we find them today, they likely lived in similar environments in the past. If you find many



clams with an absence of brachiopods and bryozoans the environment may have been muddier.

Clams vs. Brachiopods: The dorsal and ventral shells are symmetrical on a clam. Each shell of a brachiopod is symmetrical if cut in half. Imagine a sandwich.... The symmetry in clams would be represented by the two pieces of bread that make up the sandwich. The symmetry in brachiopods would be represented by cutting the sandwich in half.

[Simplify explanation]

[Add information on reading a stratigraphic column]

## APPENDIX M

### Curriculum Standards

Fossil Finders Content Matter Conceptual Matrix: Targeted NSES Standards from *Teaching about Evolution and the Nature of Science* (National Academy of Sciences, 1998)

	<b>Targeted NSES (1996) Standards for <i>Teaching about Evolution and the Nature of Science</i> for Grades 5-8 (NAS, 1998)</b>
<b>Reproduction and heredity</b>	Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species. Some organisms reproduce asexually. Other organisms reproduce sexually.
	In many species, including humans, females produce eggs and males produce sperm. Plants also reproduce sexually--the egg and sperm are produced in the flowers of flowering plants. An egg and sperm unite to begin development of a new individual. That new individual receives genetic information from its mother (via the egg) and its father (via the sperm). Sexually produced offspring never are identical to either of their parents.
	Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
	Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
	The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.
<b>Diversity and adaptation of organisms</b>	Millions of species of animals, plants, and microorganisms are alive today. Although different species might look dissimilar, the unity among organisms becomes apparent from an analysis of internal structures, the similarity of their chemical processes, and the evidence of common ancestry.
	Biological evolution accounts for the diversity of species developed through gradual processes over many generations. Species acquire many of their unique characteristics through biological adaptation, which involves the selection of naturally occurring variations in populations. Biological adaptations include changes in structures, behaviors, or physiology that enhance survival and reproductive success in a particular environment.
	Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on the earth no longer exist.
<b>Earth's history</b>	The earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet
	Fossils provide important evidence of how life and environmental conditions have changed

Nature of science	Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.
	In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work towards finding evidence that will resolve their disagreement.
	It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists.
History of science	Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.
	In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.
	Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

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